INTRODUCTION

This test plan describes the methodologies that will be used to evaluate the effects of the Advantage I-75 Mainline Automated Clearance System (MACS) on weigh stations along the Interstate 75/Highway 401 corridor between Kingston, Ontario, and Fort Meyers, Florida. The purpose of this test plan is to determine the nature and extent of benefits in weigh station productivity, vehicle safety, and reduced congestion for state enforcement officials, participating motor carriers, and the traveling public as a result of increased weigh station effkiency generated by the MACS project. The goal of this test plan is to serve as a basis for estimating the expected benefits of future deployments of electronic clearance systems on a national scale.’

This document consists of two test plans, the Weigh Station Throughput Test Plan and the Simulation Modeling Test Plan. Each of the two tests is prepared in accordance with the Intelligent Vehicle Highway Systems Operational Test Evaluation Guidelines.’ The test plans include ten major sections consisting of test descriptions, test schedules, test activities, and data reduction and analysis techniques. The weigh station throughput test describes the procedures that will be used to determine the effect of the MACS project on commercial vehicle travel time and the nature and extent of vehicle inspection and processing that occur at I-75 corridor weigh stations. The simulation modeling test describes the procedures that will be used to determine the effect of the MACS project on unauthorized weigh station bypasses, queue length, and if possible, merges and lane changes in the vicinity of I-75 corridor weigh stations.

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[1] ***The*** test plan purpose and goal is extracted from ***the Scope of Work for Preparing The Detailed Evaluation Plans.*** Submitted to the Advantage I-75 Evaluation Task Force. Prepared by the Iowa Transportation Center. April 1, 1994. p-10.

[2] ***Intelligent Vehicle Highway Systems Operational Test Evaluation Guidelines.*** Submitted to the Federal Highway Administration. Prepared by the Mitre Corp. November, 1993.

WEIGH STATION THROUGHPUT TEST PLAN

PURPOSE OF THE TEST

This test has three purposes. Primarily, the test will determine the effect of the MACS project on travel time for commercial vehicles on the I-75 corridor. Specifically, we will measure the difference between the time required by vehicles traveling through Advantage I-75 weigh stations and the time required by vehicles that are electronically cleared to bypass the same weigh stations. Next, this test will document the nature and extent of processing and inspection that occur at selected weigh stations during defined time periods. Finally, this test will collect sufficient data to run, and later to validate, the simulation modeling programs being developed to demonstrate the expected effect of the MACS project on the following weigh station conditions:

- Unauthorized weigh station bypasses
- Queue length
- Merges and lane changes (if this is found to be feasible)

OVERALL TEST RESPONSIBILITY

Acting in the capacity of Evaluation Manager, the Center for Transportation Research and Education (CTRE), is responsible for the following duties:

- Select appropriate test sites
- Obtain data describing truck arrival rates and throughput processing times at selected sites that are representative of actual conditions
- Recruit staff to assist with conducting the tests
- Procure test equipment (timing and speed monitoring devices, data collection forms, safety and communications equipment)
- Perform the tests
- Conduct the statistical analyses
- Prepare a written report summarizing the findings

EVALUATION TEST DESCRIPTION

Overview

This test is based on the results of previous MACS project planning activities and Pilot Study Two. Comparisons of travel time for vehicles electronically cleared to bypass selected weigh stations on the mainline and for vehicles routinely processed through the same weigh station will be established by collecting explicit vehicle throughput data during multiple one-hour time periods. The throughput data consist of vehicle identification and arrival time. These data are collected at three locations within the weigh station for all vehicles entering the station during one-hour time periods. The three locations are:

- Point One: upstream base of the weigh station approach ramp (point of entry)
- Point Two: static scale or primary monitoring facility located at the center of the weigh station
- Point Three: downstream base of the weigh station departure ramp (point of exit)

One or two research assistants will be stationed at each of the locations and will manually record the vehicle ID and arrival time for each arriving vehicle for a 66-minute scheduled time period, which generally begins at 0 minutes past the hour and ends at six minutes past the following hour. Six additional minutes (e.g., 66 instead of 60) of data are required to ensure that a complete data set is obtained at all observation points for each vehicle arriving at Point One during the scheduled period. Based on the results of Pilot Study Two, six minutes was shown to be adequate time for approximately 99 percent of the arriving vehicles to travel from Point One to Point Three.

The arrival time data at Points One, Two, and Three will be used to calculate the mean interarrival time and processing time at each of the selected weigh stations. The mean interarrival time is a measure of how frequently vehicles arrive at a specified point (e.g., Point One). For example, a mean interarrival time of 8.5 seconds at Point One indicates that, on average, one vehicle is arriving at Point One every 8.5 seconds. Processing time is a measure of the time required for vehicles to be processed from the beginning point of the weigh station (Point One) to the ending point of the weigh station (Point Three). Travel time savings will be established by subtracting the time required to travel the mainline distance from Point One to Point Three at observed highway speeds from the weigh station processing time. The results of the test will be a tabular listing of the mean, standard deviation, and travel time differences for 95 percent of the vehicle population at each of the selected Advantage I-75 weigh stations.[3]

The nature and extent of vehicle inspection will be determined by recording vehicle processing data for each vehicle arriving at the static scale or central processing point (i.e., Point Two) during the scheduled one-hour time period. The data recorded are an identifier code, used to designate predefined inspection scenarios, and processing time. Based on the results of Pilot Study Two, the following three inspection scenarios have been defined for this test:

- Stop at Scale: routine processing, in which the vehicle is immediately released to the mainline after the weight and credentials have been monitored
- Level One: brief inspection, in which the vehicle is first directed to park on the scale (not pulled out of queue) for a brief credential check and then released to the mainline
- Level Two: detailed inspection, in which the vehicle is pulled out of queue and directed to park at a designated inspection/parking area for further inspection or credential check

The data will be recorded simultaneously with the identification and arrival time information by the person(s) stationed at Point Two.

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[3] This tabular output will be similar to the processing time data provided in Tables II-IV on page 12 of the Evaluation Recommendations. ***Detailed Evaluation Plan Part One: Evaluation Recommendations.*** Submitted to the Advantage I-75 Evaluation Task Force. Prepared by the Iowa Transportation Center. October 18, 1995. p 12.

For each selected test site, the results of the test will be a tabular listing that provides the number of vehicles entering the weigh station, the number of vehicles that stop at the scale, and the number of Level One and Level Two inspections that occurred during the scheduled collection periods[4] Since the design of some weigh stations (Ramp WIM and High-Speed Ramp WIM) is such that not all vehicles entering the station actually arrive at Point Two, this output will also be useful in determining the probabilities of being directed to the static scale at these stations. These data will also be useful in evaluating the focused enforcement efforts that might be expected from an electronic clearance system.

This test will also collect the data that are necessary to establish and validate the simulation modeling programs being developed to evaluate the effect of the MACS project on unauthorized bypasses and queue length at selected Advantage I-75 weigh stations. These data consist of vehicle arrival speed (at Points One-Three), service time at the static scale, and the number and frequency of unauthorized bypasses that currently exist at selected test sites. The arrival speed and service time data will be measured for brief random periods (five or ten minutes) between the scheduled one-hour throughput collection sessions. The unauthorized bypass data will be collected simultaneously with the throughput data collection sessions by recording the number of unauthorized bypasses that occur during each minute of the scheduled session. Pilot Study Two revealed these unauthorized bypass rates can fluctuate between 0 and 45 percent of all arriving vehicles at selected test locations. These data will be used to better simulate the expected effects of electronic clearance on unauthorized bypasses. Detailed discussions are provided in the Simulation Modeling Test Plan, later in this document.

Hypotheses to be Tested

- **Hypotheses Two:** ‘Reduction or elimination of stops at weigh stations by participant transponder-equipped trucks will result in travel time savings for that truck.”
- **Hypothesis Six:** “Automated monitoring of weights (and credentials) of vehicles with known credential validity will result in increased incidence of cited non-compliant vehicles by MACS weigh station enforcement personnel.”

Evaluation Approach to be Used

Travel Time Savings

This test is a study that compares the travel time required for vehicles proceeding through the weigh station to that of vehicles bypassing the station at observed mainline speeds to calculate expected travel time savings resulting from electronic clearance at selected Advantage I-75 weigh stations. The data, which we refer to as throughput processing time data, will be collected at scheduled one-hour time periods that reflect both peak and non-peak traffic conditions. The test output will be a tabular listing of the mean, standard deviation, and interval describing the travel time savings for 95 percent of the truck population for each of the selected test sites. Graphical displays of vehicle inter-arrival times and processing times will also be provided.

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[4] For an illustration of this output see Table VI, ***Detailed Evaluation Plan Part One: Evaluation Recommendations.*** p. ***20.***

Credential Monitoring
This test is a survey of the nature and extent of existing inspection and credential monitoring conditions at selected Advantage I-75 weigh stations. The test simply documents the number and type of inspection and credential monitoring that occurs during scheduled time periods. The result of the test is a table that provides that probability of inspection or credential monitoring during these defined periods.

Statistical Methods to be Used to Analyze the Data

A variety of statistical methods will be used consistent with the various aims of this data collection effort. The first part of the statistical analysis of the data will be gross error checking and editing. Experience from the pilot studies suggest that one-two percent of the data records will include data entry or recording errors. Some of these errors are easily discovered; for example, a truck is recorded as having reached Point Three prior to reaching Point One.

The principal method of analysis will be to simply record summaries of the collected data. To measure time savings we will report the mean amount of time required for a truck to pass through the weigh station (based on a large sample). We will use a smaller sample of speed measurements to assess the time required for trucks that bypass the weigh station to travel a similar distance. In addition to reporting the mean savings we will report a measure of variability (the standard deviation) and an interval that describes the experiences of the middle 95 percent of the population of commercial vehicles (with others excluded as possible errors or evidence of unusual driving). The recorded data will also be used to provide information about the frequency and duration of inspections under the current system. This information will be most useful for others to assess the possible impact of electronic clearance on credential monitoring and other violations.

A second aim of the data collection is to provide data for the simulation modeling. The tables described above will be helpful, but the simulation requires additional data about the probability distribution of various random phenomena (e.g., the interval between consecutive truck arrivals or the service time for an inspection or static weighing). Our methods for determining appropriate distributions will be primarily trial-and-error. We will consider standard distributions like the exponential distribution for arrival times (or its generalized version, known as the gamma distribution) and normal distributions for processing times or speeds. The parameters of these distributions will be chosen to match the observed mean and standard deviation of the data.

Test Scheduling

The test schedule is contingent on close coordination with the test participants and test locations. The following paragraphs provide an overview of the contact names, addresses, and phone and fax numbers for key test participants and test locations.

Test Participants

Test participants include the evaluation manager, evaluation coordinator, data collection team, and statistical analysis team. Table One provides the key contact, phone and fax numbers, and role of each key test participant.

Table One: Test Participant Contacts by' Project Role

Role	Key Contact	Address	Phone/Fax
Evaluation Manager	Mr. Bill McCall	Center for Transportation Research and Education 2625 N. Loop Drive Suite 2100 Ames, IA 50010-8615	(515) 294-9501 (5 15) 294-0467
Evaluation Coordinator	Mr. Jim York	Center for Transportation Research and Education 2625 N. Loop Drive Suite 2 100 Ames, IA 50010-8615	(515) 294-7164 (5 15) 294-0467
Data Collection Team	Mr. Ed Powe	Regional Entrepreneurial Institute Kentucky State University 415 Hathaway Hall Frankfort, KY 40601	(502) 227-6172 (502 227-6763
Statistical Analysis	Dr. Hal Stem	121 Snedecor Hall Iowa State University Ames, IA 50011-1210	(5 15) 294-5582 (5 15) 294-4040

Scheduling commitments should be made to the data collection team four-six weeks prior to commencement of testing.

Test Locations

This test is extremely dependent on close coordination with the weigh stations included in the test, since many of the stations are open for only limited hours. Table Two provides the key contact name, address, and phone/fax number for each of the weigh stations included in this test.

Generally, the contacts listed in Table Two are to be notified by phone and in writing approximately one month and then again one week prior to commencement of throughput data collection.

Table Two: Weigh Station Contacts by Test Location

Test Location	Key Contact	Address	Phone/Fax
Halton, Ontario (Trafalgar North and South)	Mr. John Cowan	Ministry of Transportation 1182 North Shore Blvd. East P.O. Box 5020 Burlington ON, L7R-3Z9	(905) 637-4108 Ext 252 (905) 637-4114
Middlesex, Ontario (Putnam North and South)	Ms. Kathie Costello	Ministry of Transportation 659 Exeter Road London, ON N6E-1L3	(5 19) 649-3004 (5 19) 649-3086
Essex, Ontario (Windsor North and South)	Mr. Duncan Calder	Ministry of Transportation 2740 Dougall Avenue Windsor, ON N8X-1 T2	(5 19) 972-7349 (519) 973-1492
Monroe, Ml (Erie East and West)	Lt. Thomas Kenney	Michigan State Police 3 00 Jones Avenue Monroe, MI 48 16 1	(3 13) 242-3500 (3 13) 242-8928
Hancock/Wood, OH	Sgt. Jim Bennett	Ohio Highway Patrol 3201 North Main Avenue Findlay, OH 45840	(419) 423-1414 (419) 423-9179
Kenton, KY	Lt. Jim Sutter	Kentucky Transportation Cabinet Motor Vehicle Enforcement: P.O. Box 109 Walton, KY 41094-0109	(606) 356-l 111 (606) 356-0862
Scott, KY (Georgetown)	Lt. William Carter	Kentucky Transportation Cabinet Motor Vehicle Enforcement P.O. Box 760 Georgetown, KY 40324	(502) 863-4559 (502) 863-2124
Knoxville, TN	Capt. Richard Sayne	Tennessee Dept. of Public Safety 7601 Kingston Pike Knoxville, TN 379 19	(615) 966-5071 (615) 671-1293
Monroe, GA Forsythe)	Capt. Cliff Tackett	Georgia Dept. of Transportation 276 Memorial Drive Atlanta, GA 30303	(912) 994-l 278 (912) 993-3017
Lowndes, GA (Valdosta)	Capt. Charles Purvis	Georgia Dept. of Transportation 276 Memorial Drive Atlanta, GA 30303	(912) 244-6863 (912) 245-4331
Charlotte, FL (Punta Gorda)	Maj. Bill Mickler	Florida Dept. of Transportation 605 Suwannee Street Mail Station 99 Tallahassee, FL 32399-0450	904-488-7920 904-22 l-6627

The data collection team must be prepared to deal with a variety of scheduling issues, including some that can be anticipated and others that cannot be foreseen. Examples of the types of issues are highway construction, staffing considerations, and the 1996 Summer Olympic Games. Some of the currently anticipated issues are summarized by weigh station below.

- Halton and Middlesex, Ontario: Due to staffing constraints, these stations are only staffed and open approximately 30-40 percent of the time.
- Hancock, Ohio: Major station house renovation activities are tentatively scheduled to commence on or about June 1, 1996. Beginning on that date, the station will be closed for approximately 90 days to accommodate the construction crews.
- Monroe and Lowndes, Georgia: The staff from these stations will be reassigned to Atlanta, Georgia for the period from July 19 to August 19 to provide security services for 1996 Sumrner Olympic Games. Additionally, station house renovation activities are tentatively scheduled to begin on or about July 1, 1996 at as yet unnamed weigh stations.

Therefore, close communication with the above key contacts will be necessary to ensure that the data collection is scheduled to ensure minimum disruption to routine weigh station operations and during time periods when weigh stations are operating under normal routine operating conditions.

Required Support

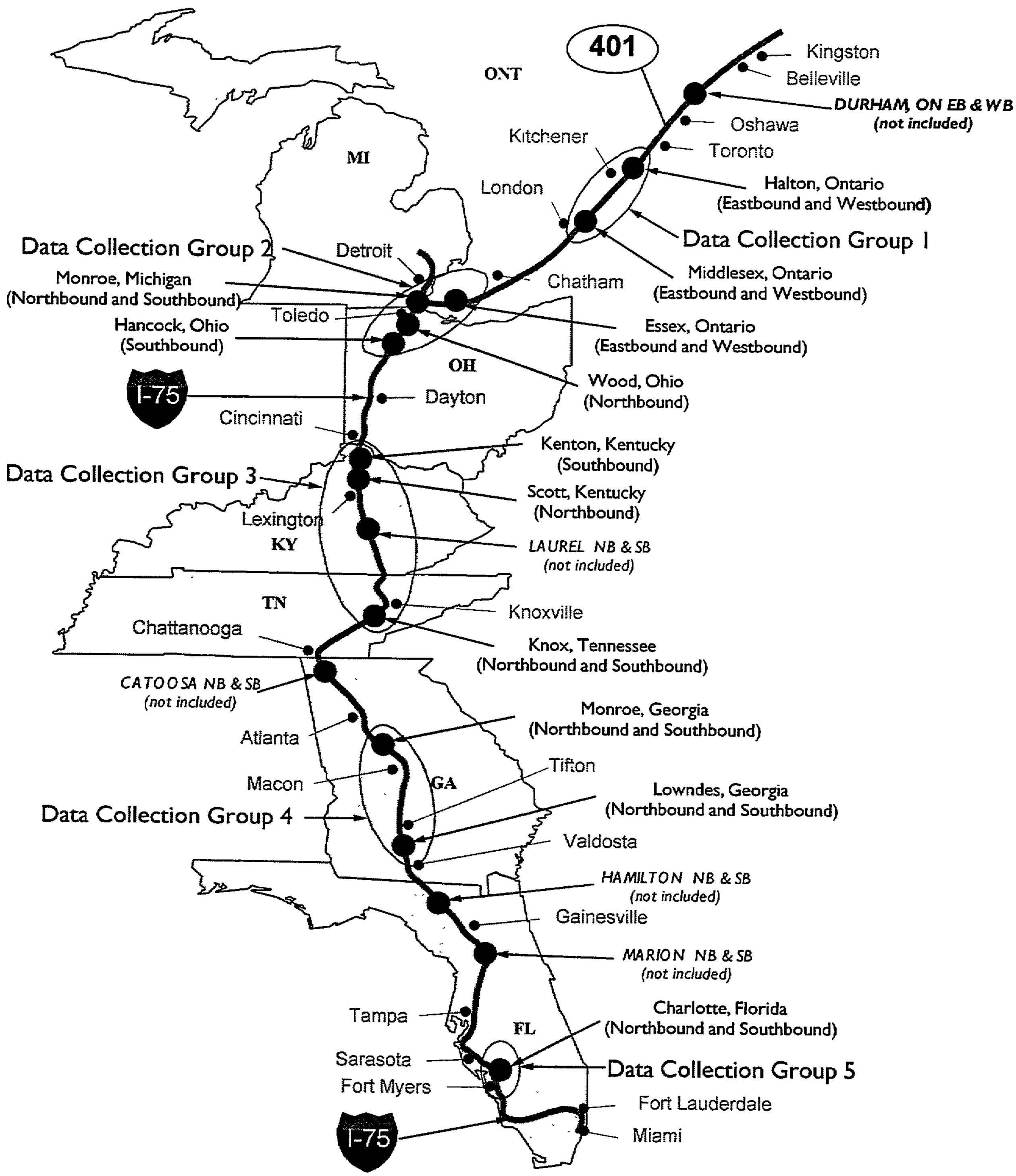
This test assumes that the enforcement officials at selected test sites will accommodate the planned data collection activities.

Test Location and Duration

An overview of the test locations is provided in Figure One. As the figure illustrates, the test will be conducted at 12 locations and 20 weigh stations (i.e., eight station-pairs and four single stations.

Data for the tests will be collected during a four-month period beginning on or about June 1, 1996. As Figure One illustrates, the test locations have been aggregated into five groups, numbered one-five, consisting of two, four, or six weigh stations per group. This grouping has been done to capitalize on the close proximity of some weigh stations to other stations and to provide the maximum amount of data for a given travel investment. Five data collection trips (i.e., one trip per group) are planned. Each trip consists of a continuous three-to-five day period beginning on a Monday or Tuesday. During each trip, the data collection crew will collect six hours of throughput timing data along with other data concerning approach and departure speed and service time. Detailed discussions of the data collection schedule are provided in the Test Activities section of this test plan.

Figure One: Overview of Test Locations



Key Conditions to be Fulfilled Before the Test Can Begin

None

Key Assumptions

None

Key Constraints

None

Security Considerations and Provisions Specific to the Evaluation Test Plan

None

Safety Considerations That Affected the Design of the Test

The primary safety consideration for this test is the welfare of the data collection crew. Members of the crew will be trained in weigh station protocol and safety procedures prior to beginning the test. The experience gained from Pilot Study Two will be useful in this area.

Privacy Considerations

None

Potential Impacts on the Operational System

No impacts on the operational system are foreseen, as the data collection procedures have been tested in Pilot Study Two and have been designed to provide minimum disruption to routine weigh station operations.

TEST SCHEDULE

The test is scheduled to begin in mid May 1996 and be completed approximately three months after the end of the MACS operational test in March 1998. An overview of the major test activities is provided below.

- Test Preparation: May-June 1996
- Data Collection: June-October 1996
- Data Analysis: October 1996--October 1997
- Final Report Preparation: November 1997-March, 1998

A Gantt Chart illustrating the above schedule is provided in Figure Two. A detailed data collection schedule for the weigh station throughput timing tests is provided in Appendix One, and a monthly overview of the combined data collection for the weigh station throughput and fuel consumption test plans is provided in Appendix Two.

. Figure Two: Evaluation Test Schedule

Task Name	1996 (01–12)	1997 (01–12)	1998 (01–12)
Test Preparation	May 96 — June 96		
Data Collection	June 96 — October 96		
Data Analysis	October 96 —	— October 97	
Report Preparation		November 97 —	— March 98

REFERENCES

The material presented in this document is a result of several preliminary planning activities. A brief review of those preliminary plans is provided in the following paragraphs.

The General Evaluation Work Plan, prepared and submitted to the Evaluation Task Force in December 1993, furnished a summary of the potential project goals, objectives, and measures of effectiveness derived from sources including initial project proposals, concept papers, or presentations. Additionally the document ranked the priority of these objectives as primary, secondary, and candidate based on their potential for being credibly evaluated and presented a ‘best-guess” budget for evaluating each of the objectives.

The Scope of Work for the Detailed Evaluation Work Plan, prepared and submitted to the Evaluation Task Force in April 1994, grouped the primary goals and objectives established in the *General Evaluation Work Plan* into sets of objectives and preliminary hypothesis tests based on their expected effects on the project stakeholders (motor carriers, weigh stations, and the various jurisdictional agencies along the Advantage I-75 corridor). The result of this grouping was five Individual Evaluation Test Plans that could be further developed to assess the effects of the MACS project on the stakeholders involved. These Individual Evaluation Work Plans are shown below:

- Motor Carrier Individual Evaluation Work Plan
- Weigh Station Individual Evaluation Work Plan
- Motor Carrier Safety Individual Evaluation Work Plan
- Jurisdictional Issues Individual Evaluation Work Plan
- Credential Compliance Individual Evaluation Work Plan
- System Individual Evaluation Work Plan

Using the November 1993 edition of the FHWA’s Operational Test Guidelines as a model, this document presented preliminary test hypotheses, test concepts, test methodologies, and budgets for developing each of the above individual evaluation work plans.

The Hypotheses Validation and Test Methodology was prepared and submitted to the Evaluation Task Force in January 1995. The purpose of this document was to present testable hypotheses and initial test methodologies, grouped by individual evaluation work plan, for 16 selected goals and objectives related to the services provided by the MACS project and six selected goals and objectives related to the performance of the MACS system hardware and software. The development of the initial test methodologies revealed that some of the selected project objectives were similar in meaning and intent and would thus require duplicate evaluation efforts. For example, Hypothesis Seven (reduced queue lengths) and Hypothesis Ten (reduced instances of "queue overflows onto the mainline") were viewed as similar in their required test methodology and therefore combined into a single hypothesis concerning the overall impact of the MACS project on weigh station queues. The development of initial test methodologies also revealed that other objectives were too vague to develop an economically feasible method of conducting a credible evaluation. For example, Hypothesis Four (improved productivity of motor carriers attributable to the efficient administration of weigh stations) was eliminated because a more direct assessment of motor carrier productivity was already contained in Hypotheses One (energy savings attributable to the MACS project) and Hypothesis Two (travel time savings attributable to the MACS project).

The Pilot Studies were developed at the direction of the Evaluation Task Force to assist in the planning of the two-year evaluation. Two pilot studies were carried out. The first focused on the Motor Carrier Individual Evaluation Work Plan and the second focused on weigh station conditions to be evaluated in the Weigh Station Individual Evaluation Work Plan. Not included in the *Scope of Work for the Development of the Detailed Evaluation Plan, these* studies were prepared between January and July 1995, and submitted to the Evaluation Task Force and Policy Committee in August 1995. The purpose of these studies is summarized below:

- Obtain information about the amount and variability of fuel consumption for various weigh station processing scenarios with and without electronic clearance.
- Determine the key predictors of certain variables of interest such as weigh station throughput, queue length, merges and lane change, and traffic congestion.
- Determine the sample size required for a credible two-year evaluation.
- Conduct preliminary analyses using the statistical methods that are likely to be used in the full-scale evaluation.
- Determine whether the proposed statistical methods are appropriate for assessing the effect of electronic clearance.
- Provide the evaluation team with experience in data collection conditions likely to be encountered during the two-year evaluation.

Similar to other preliminary planning activities, the intention of these studies was the continued refining of the two-year evaluation as a method of providing the most credible operational test evaluation for the least cost.

Detailed Evaluation Plan Part One: Evaluation Recommendations was prepared to provide members of the Evaluation Task Force with data-based recommendations concerning methodology and a preliminary budget for the two-year evaluation of the Advantage I-75 MACS project. Notes on statistical methodology were included to assist in the interpretation of the recommendations. The information provided in that document was intended to assist the Evaluation Task Force in assessing and approving a credible evaluation plan that appraises the impacts of the MACS project on the various stakeholders affected by the electronic clearance services provided.

PRE-TEST ACTIVITIES

This test plan is based on the results of an extensive pilot study that was conducted at 14 weigh stations along the Advantage I-75 corridor during June 1995. The design and planning of the pilot study is discussed in ***Pilot Studies.*** The results of the pilot study are provided ***in Detailed Evaluation Plan Part One: Evaluation Recommendations.5***

EVALUATION TEST ACTIVITIES

Description of the Test

The following paragraphs provide a detailed description of the scenarios and procedures for the weigh station throughput tests.

Scenario

It is important to evaluate the effect of electronic clearance on weigh station performance. This task is complicated by the fact that the traffic conditions at every station are affected by a number of unique factors such as topography and traffic patterns. Additional complications include seasonal variation in traffic volume and special events like construction. With the enormous number of possible scenarios a comprehensive design that would include data describing every possible traffic condition does not seem possible. Instead, we have opted to survey the stations during the summer months (when it easiest to recruit data collection members and stay within the proposed evaluation time frame) at both peak and non-peak travel times. Our aim is to provide information that is representative of the range of behavior seen at each station. Information about other scenarios (e.g., winter travel) can be obtained by simulation or extrapolation from the results obtained here.

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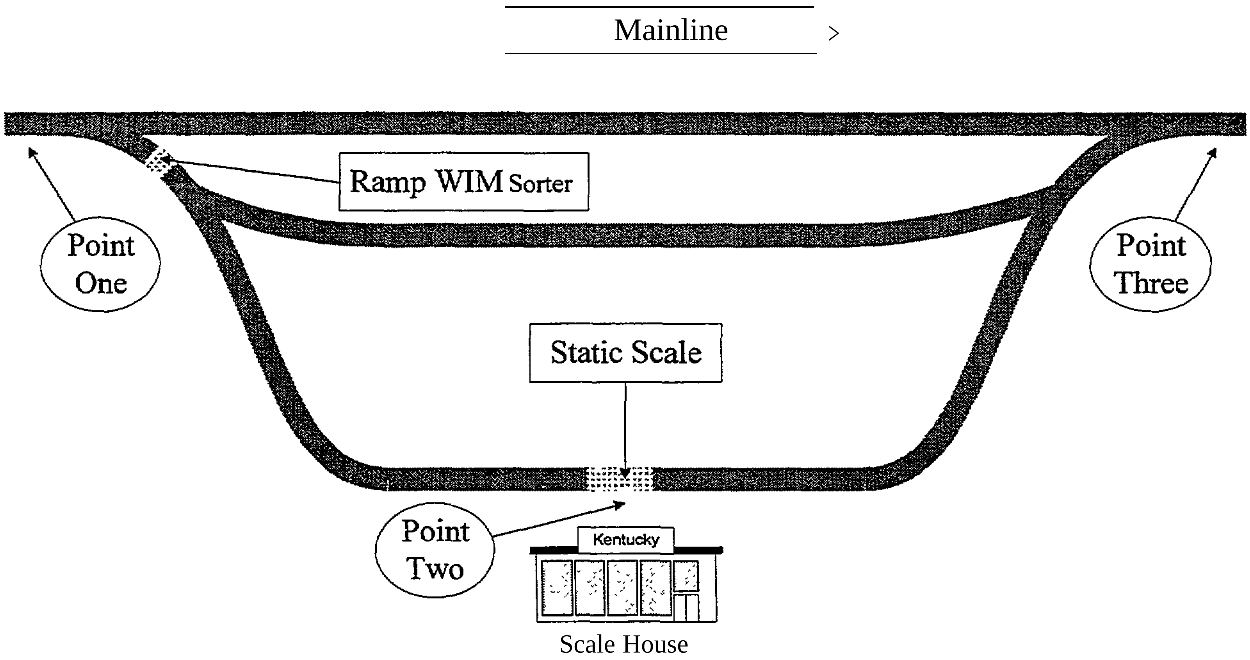
[5] ***Pilot Studies.*** Submitted to the Advantage I-75 Evaluation Task Force. Prepared by The Iowa Transportation Center. Ames, Iowa. July ***24, 1995. Detailed Evaluation Plan Part One: Evaluation Recommendations.*** Submitted to the Advantage I-75 Evaluation Task Force. Prepared by The Iowa Transportation Center. October 18, 1995.

Figure Three: Data Collection Points



Throughput Data Collection Procedures
The following paragraphs describe the procedures for recording vehicle arrival time and unique vehicle identification information at each of the three data collection points shown in Figure Three. The procedures are identical for each selected test site.

Point One Point One will be staffed by three individuals: one arrival observer, one arrival recorder, and one bypass observer/recorder. Prior to the start of the first scheduled one-hour data collection session, the data collection team leader locates and permanently marks the observation point (using a 1 "x2"x 18" pointed stake or fluorescent paint) at the location shown on the detailed weigh station site plan. (Site plans for each of the selected test sites are provided in Appendix Three.) The distance from Point One to Point Two is then measured using a surveyor's wheel and recorded on the site plan and in the right header of the first hour's Vehicle Arrival/Departure Identification Form (see page 24).

Just prior to the start of each scheduled session, the arrival recorder enters the information, such as site identification and weather information, in the header of page one of the Vehicle Arrival/Departure Identification Form (see page 24).

As the session begins, the arrival observer calls out the unique truck identification (first four digits of the prorate plate and arrival time (MM:SS) to the recorder. For example, suppose that two closely spaced (say 100 feet apart) trucks arrive at Point One shortly after the session begins. Now further suppose that the first truck, with prorate plate PR-4564, arrives at Point One at 2 minutes 14 seconds past the hour, and the second truck, with prorate plate RC-8742 arrives at Point One at 2 minutes 26 seconds past the hour. The arrival observer would announce the first truck as "PR45--02:14" and the second truck as ***"RC87--02:26.*** " The arrival recorder would record the first truck on the 2-minute line (i.e., third line from the top) on page one of the Truck Arrival/Departure Identification Form by noting PR45 on the ID line (gray-shaded) and 14 on the Secs. line (not shaded). The second truck would be recorded in the box immediately to the right of the first truck by noting RC87 on the ID line (gray shaded) and 26 on the time line (not shaded). Figure Four illustrates the above sample entries in an abbreviated version of the Vehicle Arrival/Departure Identification Form. Complete forms are shown on pages 24-26.

Figure Four: Abbreviated Vehicle Arrival/Departure Identification Form

Minute		Vehicle Identification and Arrival Time (Seconds)								
0	ID.									
	Secs.									
1	ID.									
	Secs.									
2	ID.	PR45	RC87							
	Secs.	14	26							
3	ID.									
	Secs.									

Using this system, the team can note the ID and arrival time of up to 10 trucks in any one-minute period.

Based on the results of Pilot Study Two, secondary vehicle identification procedures have been established for those instances when the vehicle's prorate plate is not immediately conspicuous. Conditions encountered during this study indicated that the view of prorate plate is obstructed on approximately 10 percent of vehicles entering the weigh station because the plate is attached to the lower portion of the trucks' front bumper on a pivoting bracket which is blown back, covered by an Oversize Vehicle sign, or otherwise not immediately visible. To ensure uniform identification of these vehicles at each of the data collection points, the following order of vehicle identification priority has been established.

1. Vehicle prorate plate/identification tag (e.g., first four digits)
2. Vehicle cab color (e.g., blue, green, white, and etc.)
3. Vehicle make (e.g., Navistar, Ford, Kenworth, Peterbilt, and etc.)

Using the above vehicle identity procedure will thus reduce or eliminate the possibility of erroneous or duplicate vehicle descriptions simultaneously residing in the throughput data set.

The bypass observer/recorder locates in the vicinity of Point One where the bypassing truck traffic can be safely observed. Based on the results of Pilot Study Two, the best location for this individual is approximately 200 feet downstream from Point One approximately 10 feet off the road shoulder. Just prior to the start of each session, this individual records the appropriate information in the header of the Truck Bypass Form (see page 27). As the session commences, this individual observes and records each commercial vehicle bypass event that is attributable to a queue overflow condition. As each bypass event occurs, this individual places a dot on the appropriate minute line of the form using a ten-dot tally system. For example, if four vehicle bypasses were observed during minute six of the session, this individual would place four dots on line six of the form.

Point Two Point Two will be staffed by either one or two individuals depending on the arrival rates and the arrival speed at the static scale. Generally the arrival speed at these sites is slow and one individual can both identify and record the needed information.

Prior to the start of the first scheduled one-hour data collection session, the data collection team leader locates and permanently marks this Point (using a l"x2"x 18" pointed stake or fluorescent paint) at the location shown on the detailed weigh station site plan.) (Site plans for each of the selected test sites are provided in Appendix Three. The distance from Point Two to Point Three is then measured **using** a surveyor's wheel and recorded on the site plan and in the header of the first hour's Vehicle Arrival/Departure Identification Form.

Just prior to the start of each scheduled session, the individual assigned to this point enters the information, such as site identification and weather information, in the header of page one of the Arrival/Departure Identification Form.

As each truck arrives this individual notes and records the unique vehicle identification, arrival time (using the method described for Point One), and processing scenario. The processing scenario is observed and recorded based on the key described in Table Three.

Table Three: Vehicle Processing Scenarios

Processing Scenario	Notation
• **Stop at scale:** Static weigh and exit	None
• **Level One:** Static weigh, credential check (while stopped on scale platform), and exit	A
• **Level Two:** Static weigh, inspection, credential check, and exit	+

For example, if a truck is weighed on the static scale and is then released to return to the mainline, no additional notations are recorded. Suppose, however, that a truck with prorate plate CY-4911 arrives at the static scale at 15:23 past the hour and is stopped on the static scale by an enforcement officer, who walks out of the scale house and asks to see the driver's logbook. Upon examining the driver's logbook, the enforcement officer then releases the truck to return to the mainline. This event would be recorded by noting "CY49" on the gray shaded ID line of the 15-minute segment line of page one of the Truck Arrival/Departure Form (i.e., 16 lines from the top), and noting "'23A" (the symbol A **is** noted for a this processing scenario) on the time line (not shaded). If the truck had been instructed to park **and** bring the credentials into the weigh station and/or the vehicle was parked for inspection, the time line portion of the event would be noted as "'23+" (the symbol + is used to denote-trucks that are static weighed, credential checked, and inspected prior to being released to the mainline).

It should be noted that not all vehicles arriving at Point One will be observed at Point Two for those weigh stations designated as Ramp WIM or High-Speed Ramp WIM design types. Pilot Study Two revealed that the majority of vehicles (77-99 percent of the total vehicles entering the station) that enter these weigh stations are immediately directed back to the mainline on a static scale bypass lane. The observer(s) at Point Two at these stations will only note the vehicle arrival, identification, and processing scenario data for those vehicles that are directed to the static scale.

The process is repeated using pages one, two, and three of the form until the session ends at six minutes past the following hour.

Point Three As Figure Three illustrates, Point Three corresponds to the point where vehicles exit the weigh station and return to the mainline. However, the term "Vehicle Arrival" is still used at this point to maintain consistency in data terminology. This point will be staffed by two individuals, one arrival observer and one arrival recorder. Prior to the start of the first scheduled one-hour session, the data collection team leader locates and permanently marks the observation point (using a 1 "x2" x 18" pointed stake or fluorescent paint) at the location shown on the detailed weigh station site plan. (Site plans for each of the selected test sites are provided in Appendix Three.)

Just prior to the start of each scheduled session, the arrival recorder enters information, such as site identification and weather information, in the header of page one of the Vehicle Arrival/Departure Identification Form.

As each truck arrives these individuals note and record the unique vehicle identification and arrival time using the method previously described for Point One. This process continues for each arriving vehicle until completion of the session at six minutes past the following hour.

Simulation Modeling Data Collection Procedures

As previously noted, one of the purposes of this test is to provide specific information needed to develop the simulation models that will be used to evaluate the effects of the MACS project on unauthorized bypasses and weigh station queue lengths. The information needed for these models is:

- Average vehicle approach speed at Points One, Two, and Three
- Average static scale service time
- Average mainline bypass speed

Average mainline bypass speed is also used to calculate the travel time differences between those vehicles electronically cleared to bypass a weigh station and those vehicles processed through the same station. The following paragraphs describe the procedure for collecting the above information.

Average Vehicle Approach Speed Approach speed is measured using a hand-held KR-55 radar gun during random ten-minute periods between the scheduled vehicle arrival/identification sessions. Using the Vehicle Approach Speed Form, one or two observers randomly measure and record the approach speed of at least 15 vehicles during these random periods. These sessions are conducted at Points One, Two, and Three, and a minimum of three random lo-minute sessions will be conducted at each point. The average vehicle approach speed at Point Two is significantly less than the vehicle approach speeds at Point One or Point Three. Additionally, Pilot Study Two revealed that vehicles approach the static scale at different speeds based on the routine operating procedures of the particular weigh station. For example, some of the weigh stations direct vehicles to come to a complete stop on the static scale, while others direct vehicles to roll over the scale at speeds ranging from three to five miles-per-hour. Therefore, the vehicle approach speed at Point Two will be observed approximately 100 feet upstream from the edge of the static scale to maintain consistency in the data set.

Average Static Scale Service Time Static scale service time is defined as the amount of time that a vehicle is stopped on the static scale and is measured using a stop watch or other similar device that is capable of accurately measuring time to the nearest one-second interval. These data are collected at the static scale for each arriving vehicle during random 1 O-minute time periods between the scheduled vehicle arrival/identification sessions.

Service time for the other processing scenarios (level one and level two) will be calculated using the following equation:

$$\textbf{Service Time (Level One/Two)} = t_{pt\ 2\text{-}3} - T_{pt.\ 2\text{-}3} + T_{static\ scale}$$

where:

$t_{pt\ 2\text{-}3}$ = the mean observed Point Two-Point Three travel time for all Level One/Two processing scenario vehicles.

$T_{pt.\ 2\text{-}3}$ = the mean observed Point Two-Point Three travel time for all Stop at Scale processing scenario vehicles.

$T_{static\ scale}$ = the mean observed static scale service time

Average Mainline Bypass Speed Mainline bypass speed is measured similar to the method used to measure vehicle approach speed. This speed is measured at a safe location just off the shoulder of the mainline. Ideally, mainline bypass speed should be measured on the mainline nearly even with the static scale location.

Resources Needed for Conducting the Test

Hardware

This test has limited hardware needs which consist of instrumentation, supplies, data collection forms, communications equipment, and safety equipment.

The instrumentation consists of:

- Four stop watches or other digital timing devices capable of measuring time of day to the nearest one-second interval
- One KR-55 hand-held radar speed gun
- One surveyor's measuring wheel capable of measuring distances up to 2,500 feet and accurate to the nearest one-foot interval

The supplies consist of:

- Two-dozen sharpened lead pencils
- One portable pencil sharpener
- Five clipboards
- 50 1"x2"x 18" pointed wooden stakes
- Four cans of fluorescent orange spray paint
- Two rolls of fluorescent orange flagging

The data collection forms consist of:

- 200 Vehicle Arrival/Identification Forms
- 200 Truck Bypass Forms
- 100 Vehicle Approach Speed Forms
- 100 Mainline Bypass Speed Forms
- 100 Static Scale Service Time Forms

The communications equipment consists of:

- Three hand-held two-way radios

The safety equipment consists of:

- Seven fluorescent orange safety vests
- First Aid Kit

Software

No software is required for the data collection portion of this test.

Consumable Items

None

Staff and Responsibilities

This test will require a staff of seven individuals, consisting of one data collection team leader and six data collection team members. The data collection team leader is responsible for supervising the collection of the data according to the procedures defined in this test plan. Specific responsibilities for this individual include:

- Training of data collection team members in rapid and accurate vehicle identification procedures
- Location and permanent marking of the defined data collection points
- Preparation of a debriefing report (see Post Test Activities)

The data collection team is responsible for collecting and ***neatly*** recording the data according to the defined procedures.

Test Duration

The preliminary schedule provided in Appendix One specifies approximately 20 days of data collection and 10 days of travel time. In addition, approximately one-month of test preparation time will be required to coordinate and finalize the test schedule with weigh station enforcement officials and assemble the materials needed for the test. The tests will be scheduled in conjunction with Motor Carrier Fuel Consumption Tests, tentatively scheduled to begin on or about June 1, 1996, and to be completed on or about September 30, 1996. Some scheduling adjustments may be required during the course of the data collection period to account for such factors as inclement weather or weigh station staffing considerations.

Selection of Sites

The primary goal of our site selection was to meet the Evaluation Task Force requirements of including stations from each of the three weigh station design types (static scale, ramp WIM, and high-speed ramp WIM), unique weigh stations, and at least one station from each state or province. The selected sites meet this aim and, in concert with Pilot Study Two, provides data on all U.S. stations and all but one pair of Canadian stations. Phone interviews were conducted with enforcement officials at each of the weigh stations along I-751401 as part of the planning for this data collection effort. During these interviews, station officials were asked when peak traffic conditions occurred, the frequency that queue overflow conditions occurred, and the weigh station procedures during queue overflow conditions. The results of those interviews are summarized in Table Four, which provides the peak traffic times and summary of peak queue conditions.

Table Four: Weigh Station Design Description

Station Name	Design Type	Peak Hours	Peak Queue Conditions
Halton, ON	Ramp WIM	7:00-9:00 am East 9:00-11:00 am & 3:00-5:00 pm West	Frequently full queues resulting in manual closing as frequently as 6 times/hour during peak . periods.
Middlesex, ON	Ramp WIM	7:00am-3:00 pm East 7:00-9:00 am & 1:00--3:00 pm West	Frequently full queues resulting in automatic station closing as frequently as 3 times/hour during peak periods.
Essex, ON	Ratnp WIM: East Static Scale: West	7:00am-3:00 pm East 7:00-10:00 am West	Frequently full queues resulting in automatic station closing as frequently as 6 times/hour during peak periods.
Monroe, MI	Ramp WIM	6:00-9:00 am North 3:00-6:00 pm South	Frequently 2,000 ft queues during peak hours. No station closings.
Wood, OH	Static Scale	5:00-9:00 am & 2:00-7:00 pm	Queue overflows onto mainline 5-7 times per hour during peaks. Manual station closing when notified by CB radio.
Hancock, OH	Static Scale	6:00-9:00 am & 3:00-6:00 pm	Queue overflows onto mainline 7-9 times per hour during peaks. Queue monitored by TV camera. Manual station closing when queue fills.
Kenton, KY (southbound only)	Ramp WIM	9:00-11:00 am	Rarely full queues. No station closings.
Scott, KY (northbound only)	Ramp WIM	6:00-9:00 am & 3:00-6:00 pm	Rarely full queues. Automatic station closing when queue fills.
Knox, TN	Static Scale	6:00am-5:00 pm	Consistently full queues. Vehicles instructed to bypass when full. No station closings.
Monroe, GA	Ramp WIM	11 :00a-4:00 pm	Seldom full queues. Manual station closing when full.
Lowndes, GA	Ramp WIM	7:00-11:00 pm South 9:00a-4:00 pm North	Seldom full queues. Manual station closing when full.
Charlotte, FL	High-Speed Ramp WIM	10:00a-5:00 pm	No full queues. No station closings.

Based on the results of those interviews, a schedule was designed to acquire as much weigh station throughput data as possible. It was determined that six additional test sites could be added for little additional cost to the test budget by capitalizing on the significant investment in travel cost. Thus by adding only six additional days of data collection, the quantity of data collected was increased by over 40 percent.

The above table illustrates that the of the 20 weigh stations included in this test, five represent the Static Scale design type, 13 represent the Ramp WIM design type, and two represent the High-Speed Ramp WIM design type.

Specification of Sample Size

The principal goal of the study is to measure the time savings that accrues to trucks that are allowed to bypass weigh stations. A secondary goal is to observe credential monitoring practices at the stations. It seems important to measure all quantities under a variety of traffic conditions. Based on information from weigh station personnel, we have created a schedule that includes hours when heavy traffic can be expected, hours when light traffic can be expected and hours when average traffic can be expected for each weigh station. It is noteworthy that due to the concentrated data collection effort it is not possible to vary the time of year or day of week. The design presented here obtains information from more stations by spending less time at any one station.

System Conditions

The test will be conducted when weigh stations are open and under routine operating conditions. No disruptions to routine operations are foreseen.

Traffic Conditions

Data will be collected during both peak and non-peak traffic conditions. (See previous discussion concerning sample size.)

Environmental Conditions

The test will be conducted regardless of weather conditions. Special "Write-in-the-Rain" data collection forms will be used during periods of rain showers.

Safety Considerations

The following safety procedures have been developed to ensure the safety of the data collection team:

- All data collection personnel will wear orange vests while stationed at any of the data collection points.

- Data collection personnel will wear hard hats when working in or around construction zones.
- Data collection personnel stationed at Point One and Point Three will be located no closer than 10 feet from the traveled portion of the roadway.

Input Data and Collection Forms

The data collection forms and input data are shown on pages 23-28. Generally, the input data recorded on these forms, such as weigh station name, location, and observation point, are self-explanatory. Other input data, such as vehicle arrival time and identification data and approach speed, have been discussed in the procedures section of this document (see pages 13-l 7). The following paragraphs provide descriptions of the remaining input data elements.

- **Vehicle Arrival/Identification Form: Point -Point Distance The** distance, measured to the nearest foot from Point One to Point Two and/or from Point Three to Point Two: Prior to the first data collection session at each test site, these points are located and permanently marked using pointed 1 “x2”x 18” wooden stakes or fluorescent orange spray paint. The distance between these points is measured using a surveyor’s measuring wheel. The distance from Point One to Point Two is recorded in the header of the Vehicle Arrival/Identification form used at Point One. The distance from Point Three to Point Two is recorded in the header of the Vehicle Arrival/Identification form used at Point Three. These distances are also recorded on the site plan kept by the data collection team leader.

- **Truck Bypass Form: Point One-Point Three Distance** The mainline distance, measured to the nearest foot, from Point One to Point Three. This distance is measured and recorded prior to the first data collection session at each site and also recorded on the site plan kept by the data collection team leader.

- **Truck Bypass Form: Number of Bypasses** The minute-by-minute count of trucks that bypass the weigh station during the one-hour data collection sessions. This count is recorded using either a four-bar and slash tally (for counting by 5s) or a ten-dot tally (for counting by 10s).

- **Vehicle Approach Speed Form: Approach Speed . The** speed, measured to the nearest one mile per hour, of vehicles approaching the designated observation point. This speed is measured using a KR-5.5 hand-held radar speed gun.

- **Mainline Bypass Speed Form: Bypass Speed** The speed, measured to the nearest one mile per hour, of vehicles (cars and trucks) that bypass the weigh station on the mainline. This speed is measured using a KR-55 hand-held radar gun.

- **Static Scale Service Time Form: Service Time** The time, measured to the nearest one second, that trucks are stopped while being weighed or otherwise processed on the static scale.

Figure Five: Vehicle Arrival/Identification Form

Weigh Station Name:		Traffic Direction: (circle one) North South	
Observation Point: (circle one) 1 2 3	Date:		Session Start Time:_________________
Observer Name:		Recorder Name:	
Weather Conditions:		Point____-Point____Distance:_________________	

Minute		Vehicle Identification and Arrival Time (Seconds)									
0	ID.										
	Secs.										
1	ID.										
	Secs.										
2	ID.										
	Secs.										
3	ID.										
	Secs.										
4	ID.										
	Secs.										
5	ID.										
	Secs.										
6	ID.										
	Secs.										
7	ID.										
	Secs.										
8	ID.										
	Secs.										
9	ID.										
	Secs.										
10	ID.										
	Secs.										
11	ID.										
	Secs.										
12	ID.										
	Secs.										
13	ID.										
	Secs.										
14	ID.										
	Secs.										
15	ID.										
	Secs.										
16	ID.										
	Secs.										
17	ID.										
	Secs.										
18	ID.										
	Secs.										
19	ID.										
	Secs.										

Minute	Vehicle Identification and Arrival Time (Seconds)									
20 ID.										
Secs.										
21 ID.										
Secs.										
22 ID.										
Secs.										
23 ID.										
Secs.										
24 ID.										
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39 ID.										
Secs.										
40 ID.										
Secs.										
41 ID.										
Secs.										
42 ID.										
Secs.										

Minute		Vehicle Identification and Arrival Time (Seconds)									
43	ID.										
	Secs.										
44	ID.										
	Secs.										
45	ID.										
	Secs.										
46	ID.										
	Secs.										
47	ID.										
	Secs.										
48	ID.										
	Secs.										
49	ID.										
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50	ID.										
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51	ID.										
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52	ID.										
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56	ID.										
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57	ID.										
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58	ID.										
	Secs.										
59	ID.										
	Secs.										
00	ID.										
	Secs.										
01	ID.										
	Secs.										
02	ID.										
	Secs.										
03	ID.										
	Secs.										
04	ID.										
	Secs.										
05	ID.										
	Secs.										

Figure Six: Truck Bypass Form

Weigh Station Name:			Traffic Direction: (circle one) North South	
Observer Name:			Date:	Session Start Time:________
Point One-Point Three Mainline Distance:________________(ft.)				
Minute	**Number of Truck Bypasses**		**Minute**	**Number of Truck Bypasses**
0			30	
1			31	
2			32	
3			33	
4			34	
5			35	
6			36	
7			37	
8			38	
9			39	
10			40	
11			41	
12			42	
13			43	
14			44	
15			45	
16			46	
17			47	
18			48	
19			49	
20			50	
21			51	
22			52	
23			53	
24			54	
25			55	
26			56	
27			57	
28			58	
29			59	

Figure Seven: Vehicle Approach Speed Form

Weigh Station Name:		Traffic Direction: (circle one) North South		
Observer Name:		Date:		Obs. Point: 1 2 3
Observation Time	**Approach Speed (mph)**		**Observation Time**	**Approach Speed (mph)**

Figure Eight: Mainline Bypass Speed Form

Weigh Station Name:		Traffic Direction: (circle one) North South		
Observer Name:		Date:		
Observation Time	**Bypass Speed (mph)**		**Observation Time**	**Bypass Speed (mph)**

Figure Nine: Static Scale Service Time Form

Weigh Station Name:			Traffic Direction: (circle one) North South	
Observer Name:			Date:	
Observation Time	**Service Time (seconds)**		**Observation Time**	**Service Time (seconds)**

POST-TEST ACTIVITIES

Participants in the Post-Test Activities

Staff from CTRE and the Kentucky State University data collection team will perform all post test activities.

Debriefings

The data collection team leader shall prepare a written report for each test site that provides a summary of the test events, test conditions, and special circumstances that occurred during the data collection sessions. The testevents summary should consist of a brief paragraph describing the method used by enforcement officials to process vehicles through the weigh station and a description of the data collection point locations (e.g., how the point was marked and distance to nearest reference points). The test conditions summary should consist of a description of the traffic conditions and environmental conditions encountered during the data collection sessions. The special circumstances summary should describe any special enforcement or inspection efforts or construction activities in the vicinity of the weigh station that occurred during the sessions. The purpose of this debriefing is to provide information for data analysis and reduction personnel that would highlight or explain any abnormal test data. This debriefing should be completed within three days of completion of the data collection sessions.

Equipment Tear Down

None

Data Retention Plan

Completed data collection forms will be kept in a loose-leaf, three-ring notebook with separate tabbed sections for each type of form used. A separate three-ring notebook will be used for each data collection group. The data collection team leader will be responsible for collecting the forms, placing them in the notebook, and forwarding the completed notebook to CTRE for data reduction and analysis.

DATA REDUCTION AND ANALYSIS

Participants

Data from the weigh station throughput tests will be entered into computer databases, analyzed, and interpreted by personnel from CTRE at Iowa State University, in consultation with Professor Hal Stem, Department of Statistics, Iowa State University. Two research assistants at CTRE will encode the data into a Lotus Approach database.

Hypotheses or Expected Results

There is no doubt that electronic clearance will provide travel time savings for commercial vehicles. The evaluation goal is therefore to estimate the magnitude of these savings by collecting data at a number of stations. The amount of time saved will depend on the weigh station design type (Static Scale, Ramp WIM, or High-Speed Ramp WIM) and the topography and layout of the station. We have chosen to visit a number of stations to get a wide range of results. The second aim of the study concerns the hypothesis that electronic clearance will allow for more efficient use of weigh station personnel. Although formal evaluation of this hypothesis does not seem possible, we expect that a record of current inspection practices will be useful for further study of this issue. The final aim of the study is to obtain information that can be used for weigh station simulations. Although the collection of such information does not directly impact any specific hypothesis, the simulations based on this information will be used to address hypotheses concerning unauthorized bypasses and queue length in the weigh station.

Input Data

The completed forms from each of the data collection sessions will be the input data source. For each 66-minute session, the arrival time and processing scenario for each truck at Points One, Two, and Three will be entered into four fields of a database program such as Lotus Approach or Microsoft Access. The four fields are shown below:

- Point One Arrival Time
- Point Two Arrival Time
- Processing Scenario
- Point Three Arrival Time

The basic units of measurement are arrival time in the form HH:MM:SS as expressed on the 24-hour clock and processing scenario expressed as 0, 1, or 2. The vehicle identification information will be used to identify the vehicles' arrival time at each of the three points. Separate files will be maintained for each data collection session, and the data will be exported in ASCII file format to a statistical analysis program.

The truck bypass, approach speed, and service time data will be entered into a spreadsheet program and exported to a statistical analysis program in ASCII file formats.

Methods, Algorithms, and Equations Used for Generating Each Type of Output

The statistical methods required for this test are quite modest. We will create tables summarizing the observed data. These tables will contain mean travel times, standard deviations of travel times, and a range of observed travel times. In addition, we will tabulate the frequency of the various types of inspections that are performed.

The statistical analysis in this case will be based on observations of individual trucks, with the total number of observations expected to be about 25,000. This suggests that data entry and data recording errors will occur (e.g., trucks found to be at Point Three prior to their appearance at Point One). A first-stage analysis will look for observations that do not seem physically possible. Such errors will be corrected if possible or deleted in unexplained cases.

The distribution of truck mean interarrival times and processing times are of interest in planning and validating the simulation study that will be used to address questions about queue length and unauthorized bypasses. The data collected here will provide empirical distributions for these elements. We plan to relate these empirical distributions to theoretical models (like the exponential distribution and normal distribution). The theoretical models are characterized by one or two unknown parameters. These parameters will be estimated using the method of moments. The method of moments chooses the unknown parameters to match the moments (e.g., mean and variance) of the theoretical models to the observed data. Graphical displays overlaying the theoretical distribution and the observed distribution will be provided.

Statistical Tests

There is no plan to carry out statistical tests. The large-scale survey will provide accurate estimates of the time savings due to electronic clearance. A formal test of whether the time saved is greater than zero is possible but not of great interest.

Output Data

The primary output from this test will be tables describing the time savings and frequency of inspection at the different weigh stations. Examples of the type of tables that will be provided *can* be found on page 12 and page *20* of *Detailed Evaluation Plan Part One: Evaluation Recommendations.* In addition, graphical displays of the distributions of mean interarrival and processing times along with the theoretical models to be used in simulation will be provided here.

Accuracy Requirements

Tables will provide an indication of the sample size on which the data are based as indication of the accuracy provided. No formal accuracy requirements are anticipated.

Hardware, Software

The data files from each of the 66-minute sessions will be merged into one master file and formatted by session number, date, and test site. This master file could potentially contain records for 25,000 truck arrivals. Therefore a personal computer with a Pentium-based 100 MHZ or faster processor is suggested for the analysis portion of this test. A color plotter will also be used for plotting the mean interarrival and processing time distributions. The software needed for data analysis includes a spreadsheet program (e.g., Lotus 123 or Microsoft Excel), a database program (e.g., Lotus Approach or Microsoft Access), and a statistical analysis package (e.g., MINITAB or SAS).

REPORTING REQUIREMENTS

A final report outline will be developed during the course of the research. As part of the analysis and reporting phase, draft final report outlines will be developed and submitted to Evaluation Task Force members for review and comment. The final report will reflect the comments and input from committee members.

BUDGET

The budget for conducting the Weigh Station Throughput Test is provided in Table Five. This budget provides two separate expense subtotals (e.g., personnel and equipment and travel). The total project budget for this plan is the sum of the personnel and equipment subtotals and the Iowa State University indirect cost. The project term begins on June 1, 1996 and runs through March 31, 1998. The budget has been reviewed and approved, as shown in Exhibit A of the letter of transmital, by the Director of the Center for Transportation Research and the Contracts and Grants Officer for the Iowa State University.

Table Five: Weigh Station Throughput Test Plan Budget

Personnel Budget	Time (Hrs)	Rate/ Hour	Budget
Faculty			
Tom Maze	30	$55.94	$1,678
Hal Stern	173	$35.47	$6,148
Professional and Scientific			
Jim York	693	$19.87	$13,774
Bill Mc Call	60	$3 8.20	$2,292
Marcia Brink	12	$16.51	$198
Jan Graham	77	$18.69	$1,434
Merit Staff			
Dianne Love	99	$14.44	$1,434
Secretary	104	$13.74	$1,434
Research Students			
Iowa State University Student (Test Prep. & Data Collect.)	520	$14.64	$7,611
Iowa State University Student (Data Entry)	520	$14.64	$7,611
Post Doctorial Research Associate			
Dr. Ali Kamyab	$19.23	$20.19	
Fringe Benefits			
Faculty Fringe @24.55%		24.55%	$1,921
Professional and Scientific Fringe @30.8%		30.80%	$5,45 1
Merit Fringe @ 39.45%		39.45%	$1,131
Research Student Fringe @$625/year		$178.00	$534
Post Doctoral Fringe Benefits		0.16	$0
Total Personnel Budget			$52,650
Equipment and Travel Budget			
Supplies			$250
Equipment (Computer and Monitor)			$3,500
Phone, postage, and communications equipment rent			$2,000
Subcontracts			
Kentucky State University (6 Research Assitants)	1,538	$14.53	$22,340
Kentucky State University Van	4,929	$0.22	$1,084
Meals and Lodging Expense			$9,653
Additional Domestic Travel	Cost Per Trip	$1,160.00	$6,960
Tofal Equipment and Travel Budget			**$45,787**
Subtotal Project Budget			**$98,437**
Indirect Cost @25%*			$21,261
Total Project Budget			**$119,698**

SIMULATION MODELING TEST PLAN

PURPOSE OF THE TEST

The purpose of this test is to evaluate the effect that the Advantage I-75 Mainline Clearance Operational Test (MACS) has on weigh station queue length and the number of unauthorized bypasses resulting from weigh station overcrowding.

OVERALL TEST RESPONSIBILITY

As evaluation manager for this individual test plan, CTRE is responsible for the following duties:

- Select sites to use in the simulation studies
- Develop simulation modeling software that includes a graphical display of weigh station environment for selected sites
- Validate simulation model using data collected during the weigh station throughput timing tests and Pilot Study Two which collected similar information for other weigh stations
- Prepare a report summarizing the simulations' estimates of MACS effects for a variety of MACS scenarios

EVALUATION TEST DESCRIPTION

Overview

Data collected during the pilot studies indicates that long weigh station queues and unauthorized bypassing of stations due to overcrowding are common on the I-75 corridor. The small number of MACS transponder-equipped trucks during the evaluation period suggests that it will not be possible to measure significant changes in these situations during the two-year MACS evaluation. The decrease in queue length and unauthorized bypasses is likely to be quite small when only one or two percent of the total vehicle population is MACS transponder-equipped. In addition, there is extensive variability due to such factors as local traffic. Therefore, a simulation model will be developed to estimate the potential effect of MACS on queue length and unauthorized bypasses. Simulation can be used to assess the expected improvement under various assumptions about the proportion of MACS-equipped vehicles.

This test will build on earlier weigh station simulation modeling developed by the Applied Physics Laboratory at the Johns Hopkins University using the Arena simulation software. The software is quite sophisticated and can provide continuous animated displays of a number of parameters such as traffic flow, queue behavior, and processing time at the weigh stations along the I-75 corridor. The flexibility of this simulation program, combined with the rich data source provided by the weigh station throughput timing tests, will allow the evaluation team to illustrate the expected effect of many electronic clearance scenarios (e.g., varying the population of MACS-equipped vehicles) on the primary variables of interest (unauthorized bypasses and queue length). In addition, other variables of interest, such as current and expected travel time savings attributable to electronic clearance, will be incorporated in the simulation model and graphically illustrated to assist key decision makers in evaluating their investment in electronic clearance technology.

These models will be validated using the data collected from weigh station throughput timing tests and Pilot Study Two.

Pilot Study Two also revealed that other parameters of interest, such as the effect of the MACS project on merges and lane changes in the vicinity of the weigh station, cannot be effectively evaluated using traditional data collection and analysis procedures. The variability in the number of merges and lane changes attributable to each truck (expected size effect) is quite large due to many other relevant factors, and the effect of other traffic (cars and other non-commercial vehicles) on merges and lane changes significantly adds to the complexity of simulation modeling. However, a credible evaluation of the MACS project would not be complete without investigating the current and expected effects of electronic clearance on these factors related to traffic safety. The FHWA's Turner-Fairbank Highway Research Center has indicated that the capability to assess these factors using simulation is currently being developed. The evaluation team will forward the Pilot Study Two data and other throughput timing data to Turner-Fairbank for further investigation. Should the findings of Turner-Fairbank research result in information that could add to the credibility of the evaluation, the evaluation team may include the results of the Turner-F&bank investigation in the final evaluation report.

Hypotheses to be Tested

The primary hypotheses to be investigated during this test are shown below.

- **Hypothesis Five:** Automated monitoring of weights (and credentials) at MACS weigh stations will allow weigh stations to weigh more trucks per unit of time.
- **Hypothesis Seven:** The mainline electronic clearing of MACS transponder-equipped vehicles and increased throughput capabilities of MACS-equipped weigh stations will reduce the queue lengths at weigh stations along the Advantage I-75 corridor.

The secondary hypotheses to be investigated during this test are shown below.

- **Hypothesis Two:** Reduction or elimination of stops at weigh stations by participant transponder-equipped trucks will result in travel time savings for that truck.
- **Hypothesis Nine:** Electronically cleared vehicles driving by a weigh station will reduce the number of merges and lane changes within one mile of a MACS weigh station.

Evaluation Approach to be Used

A simulation model will be used to evaluate the MACS effect on reducing trucks' travel time, unauthorized bypasses, and queue length at weigh stations. The model will be developed for a limited number of sites; however, the model's flexibility allows it to be easily modified to simulate other weigh stations along the I-75 corridor. The simulation model will be coded in Arena, which provides an integrating environment for graphically building a model using SIMAN simulation language. The animation capability of Arena enables users to view the changes in performance of the weigh stations resulting from MACS implementation.

Statistical Methods to be Used to Analyze the Data

The output of the simulation model includes data that describe weigh station performance. These data, produced in summary form, include the proportion of trucks bypassing the weigh station without authorization, queue length, and processing time at the weigh station. These summaries also provide a measure of the precision of the estimates. The data collected and analyzed as part of the Weigh Station Throughput Timing Test will also be used in the simulation models. These data will be produced in statistical summary form and will include mean, standard deviation, and distribution of a number of variables. These statistical summaries will be used as input data for the simulation model and to check that the simulation model can reproduce real conditions.

Test Scheduling

A simulation model will be developed at CTRE while data are being collected for other hypothesis evaluation plans. Following data collection and simulation model development, CTRE will carry out a program of simulating selected sites under a variety of assumptions about the scope of electronic clearance and commercial vehicle traffic.

Required Support

Support of weigh station personnel is required for the data collection aspects of the study. This is discussed in detail in the Weigh Station Throughput Test Plan. The only other support required is computer hardware and software support that will be provided within CTRE.

Test Location and Duration

Data collection location and duration is discussed in the Weigh Station Throughput Test Plan. Remaining simulation development will occur at CTRE over the period from October 1996 to October 1997.

Key Conditions to be Fulfilled Before the Test Can Begin

One license for the Arena simulation software package must be purchased before the simulation modeling can begin. CTRE has purchased this license to expedite the development of the MACSIM model.

Key Assumptions

The principal assumption is that simulation will be able to reproduce observed traffic and station operating patterns, given information about trucks' mean interarrival times, weigh stations' service times and various other quantities. Assuming that we can realistically simulate current station performance, our intention is to consider a range of plausible future scenarios. Such scenarios will occasionally represent extrapolation from existing data and must therefore be viewed with caution.

Key Constraints

None

Security Considerations and Provisions Specific to the Test Plan

None

Safety Considerations Affecting the Design of the Test

The only safety considerations are those related to data collection, which are detailed in the Weigh Station Throughput Test Plan.

Privacy Considerations

None

Potential Impacts on the Operational System

We expect limited system impact during the data collection effort and no impact after that point.

TEST SCHEDULE

The test is scheduled to begin in mid May 1996 and be completed approximately three months after the close of the MACS operational test, in March 1998. An overview of the major test activities is provided below:

- Develop prototype simulation model: June 1, 1996 -- September 15, 1996
- Collect throughput data: June 15, 1996--September 15, 1996
- Develop selected site models: October 1, 1996-April 15, 1997
- Collect additional validation data: April 15, 1997-June 15, 1997
- Refine selected site models: June 15, 1997-October 3 1, 1997
- Prepare written report: November 1, 1997-March 3 1, 1998

A Gantt Chart illustrating the schedule is provided in Figure Ten. As the schedule illustrates, a prototype model will be developed using the Pilot Study Two data simultaneous with the throughput data collection. The schedule also illustrates a data recollection period for further calibration of the simulation model.

Figure Ten: Evaluation Test Schedule

Task Name	1996	1997	1998
Develop Prototype Model	June, 96 — September, 96		
Collect Throughput Data	June, 96 — September, 96		
Develop Site Models	October, 96 — April, 97		
Collect Validation Data		April 97 — June, 97	
Refine Selected Site Models!		June, 97 — October, 97	
Prepare Written Report		November, 97 — March, 98	

REFERENCES

The four primary references used in this test plan are the Pilot Studies, Evaluation Recommendations, the Weigh Station Throughput Test Plan, and the MACS Functional Requirements Document.

The Pilot Studies were developed at the direction of the Evaluation Task Force to assist in the planning of the two-year evaluation.[6] Two pilot studies were carried out. The first focuses on the Motor Carrier Individual Evaluation Work Plan, and the second focuses on weigh station conditions to be evaluated in the Weigh Station Individual Evaluation Work Plan. Not included *in the Scope of Work for the Development of the Detailed Evaluation Plan, these* studies were prepared between January and July 1995 and submitted to the Evaluation Task Force and Policy Committee in August 1995. The purpose of these studies is summarized below:

- Obtain information about the amount and variability of fuel consumption for various weigh station processing scenarios with and without electronic clearance.
- Determine the key predictors of certain variables of interest such as weigh station throughput, queue length, merges and lane change, and traffic congestion.
- Determine the sample size required for a credible two-year evaluation.
- Conduct preliminary analyses using the statistical methods that are likely to be used in the full-scale evaluation.
- Determine whether the proposed statistical methods are appropriate for assessing the effect of electronic clearance.
- Provide the evaluation team with experience in data collection conditions likely to be encountered during the two-year evaluation.

6 ***Pilot Studies.*** Submitted to the Advantage I-75 Evaluation Task Force. Prepared by the Iowa Transportation Center. Ames, Iowa. July 24, 1995.

Similar to other preliminary planning activities, the intention of these studies was the continued refining of the two-year evaluation as a method of providing the most credible operational test evaluation for the least cost.

Detailed Evaluation Plan Part One: Evaluation Recommendations was prepared to provide members of the Evaluation Task Force with data-based recommendations concerning methodology and a preliminary budget for the two-year evaluation of the MACS project.[7] Notes on statistical methodology were included to assist in the interpretation of the recommendations. The information provided in that document was intended to assist the Evaluation Task Force in assessing and approving a credible evaluation plan that appraises the impacts of the MACS project on the various stakeholders effected by the electronic clearance services provided.

The Evaluation Recommendations proposed the use of simulation modeling for assessing the expected MACS effect on unauthorized bypasses for several reasons. First, Pilot Study Two revealed that aggregate truck arrival information cannot distinguish the unauthorized bypasses that occur at weigh stations that are perpetually overcrowded from those that occur at weigh stations with extreme minute-by-minute fluctuations in truck arrivals. Pilot Study Two revealed that these fluctuations in the rate of truck arrivals, known as "platooning," can cause the same amount of unauthorized bypasses in a given time period as those that occur at perpetually busy stations. Second, simulation models provide the opportunity to extrapolate beyond the two-year operational test period to years when transponder-equipped trucks would constitute more than one or two percent of the total commercial traffic.

The Weigh Station Throughput Test Plan provides the data collection techniques, statistical analysis methods, and data collection schedule for obtaining the data needed as simulation model inputs and to validate the simulation model.*

The Functional Requirements Document provides a description of the hardware and software components that comprise MACS.[9] Consisting of four major sections, this document provides the operational, functional, physical, and performance characteristics of each of the MACS subsystems and their components.

PRE-TEST ACTIVITIES

The principal pre-test activities for this test include Pilot Study Two and preliminary model development by the Applied Physics Laboratory (APL) at Johns Hopkins University. The results

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[7] ***Detailed Evaluation Plan Part One: Evaluation Recommendations.*** Submitted to Advantage I-75 Evaluation Task Force. Prepared by the Iowa Transportation Center. Ames, Iowa. October 18, 1995.

[8] ***Detaiied Evaluation Plan Part Three: Weigh Station Throughput Test Plan.*** Submitted to the Advantage I-75 Evaluation Task Force. Prepared by the Center for Transportation Research and Education. Ames, Iowa. May 15, 1996.

[9] ***Functional Requirements Document.*** Prepared for the Kentucky Transportation Cabinet. Prepared by Science Applications International Corporation. March 8, 1996.

of Pilot Study Two are summarized in the Evaluation Recommendations. This study collected and analyzed data describing existing traffic conditions at 14 weigh stations along the Advantage I-75 corridor and determined that some of the conditions, such as unauthorized bypasses and queue length, cannot be effectively evaluated using traditional data collection and statistical analysis techniques.

The Applied Physics Laboratory at Johns Hopkins University developed a prototype weigh station simulation model for the Knox County, Tennessee weigh station using the physical characteristics of that station and commercial vehicle traffic data obtained from the Oregon Department of Transportation.

The APL simulation model was developed using the Arena simulation software. The APL model simulates and displays the flow of commercial vehicle traffic on an approximate one-mile-long segment of the I-75 mainline in the vicinity of the Knox County, Tennessee weigh station. Commercial vehicle arrivals at a point upstream from the station are generated using data-based estimates for the distribution of mean interarrival rates. As each depicted commercial vehicle approaches the station, an electronic clearance bypass or pull-in decision is generated. The bypass/pull-in decision is based on the vehicle's credential status, the current status of the static scale queue (e.g. queue full or not), and whether or not the vehicle is transponder equipped. A vehicle with a "pull-in" flag enters the weigh station and approaches the static scale. The impact of the MACS system in reducing unauthorized bypasses and queue length at the weigh station can be examined by running the APL simulation model under different scenarios.

The APL simulation model allows a user to change some of the model's parameters, such as the number of transponder-equipped vehicles or traffic volume, to examine the effect of electronic clearance in different traffic conditions. In addition to a text output file, which provides statistical information about different components of the weigh station's performance, the model produces two sets of formatted files. These files can be read by a Lotus or Excel spreadsheet program and contain one data record for each simulated vehicle that either bypasses or enters and exits the weight station.

The APL simulation model illustrates lane changing activities on the I-75 mainline. However, the lane changes illustrated in the prototype model are only a cosmetic effect, since the model does not include any algorithm to capture the mutual interaction of vehicles on the freeway. This interaction is an essential element of a lane-changing algorithm development.

Our preliminary analysis of the APL simulation model indicates that it has not been validated with real data. Validation of a simulation model is essential to assess its ability to accurately simulate existing and future weigh station conditions. This raises several concerns regarding the credibility of the two-year MACS evaluation. First, the APL model the evidence suggests that the APL has not been constructed using the complete MACS logic as defined the most recent version of Functional Requirements Document. The final MACS simulation model should reflect the as-built MACS logic to accurately portray the existing and future conditions at Advantage I-75 corridor weigh stations. Second, any simulation model must be verified and debugged to assure that there are no errors in the programming script used to model the weigh station traffic flow. It would be inappropriate to base evaluation conclusions on a simulation model with inherent errors. Third, the level of statistical precision of the input data used in the APL model has not been established. The data used as input for the MACS simulation model should meet the levels of precision that have been previously defined in previous MACS evaluation planning activities.

As the preliminary prototype, however, the APL model will be helpful in our development of a detailed and accurate model for selected weigh stations along the I-75 corridor.

EVALUATION TEST ACTIVITIES

Participants

Dr. Ali Kamyab, post doctoral research associate at CTRE will develop the simulation models. Dr. Kamyab is familiar with the SIMAN programming language used in the Arena software and has developed a simulation model to evaluate a new strategy that optimizes traffic signal timing given the presence of commercial vehicles in the traffic flow. Data collection will be supervised by Mr. Jim York, motor carrier specialist at CTRE and individuals from the Kentucky State University will assist in the data collection effort. Dr. Hal Stern of the Department of Statistics at the Iowa State University will provide guidance in the analysis of statistical data that are used and produced as simulation model inputs and outputs.

Description

Simulation is a process of modeling the operation of an actual system. Its purpose is to provide a better understanding of the behavior of actual systems and to evaluate the potential modifications of the system design. Computer simulation is a well known and powerful tool for testing the impact of changes in variables or parameters for systems where the effect of such changes cannot be determined analytically. One example in which simulation is useful is to evaluate traffic experiments which, for one reason or another, cannot be easily carried out and measured in the field. The MACS evaluation is an example of a complex system where observational studies aimed at estimating the MACS potential to reduce queues and unauthorized bypasses would be costly or impossible. In addition, part of the evaluation goal is to extrapolate beyond the two-year operational test. Thus, a simulation model will be used to evaluate the effectiveness of MACS at selected weigh stations along the I-75 corridor.

The APL simulation model has partially incorporated MACS logic and will be examined in developing an accurate simulation model for the MACS project. The new MACS simulation (MACSIM) model will fully integrate the MACS electronic clearance logic that is specified in the Functional Requirements Document."

Functional Requirements Document. Prepared for the Kentucky Transportation Cabinet. Prepared by Science Applications International Corporation. March 8, 1996.

The MACSIM model will consist of two modules: a link module and a node module. The link module will be responsible for generating and moving trucks on the freeway and registering arriving trucks. The node module will emulate traffic operation within the weigh station.

Car-following and lane-changing algorithms will not be incorporated in the link module of MACSIM due to budgetary and staffing constraints. As previously discussed, part of this evaluation test plan calls for data to be provided to the FHWA's Turner-Fairbank Highway Research Center for studying the impact of MACS in reducing lane changes and merges.

The primary emphasis of the MACSIM model is on the node module that simulates the traffic operation in a weigh station. The completed node module will then be integrated with the link module to study the impact of MACS in improving traffic throughput and efficiency of weigh stations along the I-75 corridor. For example, by measuring the queue length and the time that trucks spend in a weigh station before and after implementation of MACS (i.e., running the model when the MACS system is on and off), changes in trucks' travel time can be studied. The study of unauthorized bypasses would be done in a similar manner.

For each of the selected weigh stations (see site selection discussion on page 44), a unique MACSIM model will be developed to accommodate the structure and the functionality of a given station. The MACS logic used in the simulation is common to all of the weigh stations along the I-75 corridor, so the MACSIM model can be customized to account for each weigh station's specifications.

To determine whether a simulation model is operating correctly and whether it is actually simulating a real-world situation, it has to be verified and validated. Verification or debugging is the process of determining that a model operates as intended. Validation, on the other hand, is the process of reaching an acceptable level of confidence that the inferences drawn from the model are correct and applicable to the real-world system being simulated.

The MACSIM model will be carefully verified and validated. The trace feature of the Arena software will allow us to verify the model by examining the flow of data through the model and detecting possible errors. Once the model is verified, it will be validated by comparing the simulation results to results obtained during the Pilot Study Two and the Weigh Station Throughput Test Plan data collection. For example, the simulated weigh station processing times (e.g., actual time that each truck spends in a weigh station) will be compared to the processing times measured in the field.

Validation of the model will make use of statistical methods and external knowledge about the variables of interest. It is not expected that the quantities measured during the simulation (e.g., processing time) will exactly match the data collected in the field. The main reason for the failure to match results is that the data collected in the field is subject to many factors that are not part of the simulation (e.g., local traffic and construction activity, periods of increased or decreased enforcement activities). Statistical methods can be used to account for the variation observed in the field. For example, a significance test might be used to determine whether there is any real difference between the mean processing time for a truck in the simulation and the mean processing time for a truck on the highway. It should be emphasized that even statistical results may not invalidate the simulation model. In cases with large samples, even small differences will be determined to be statistically significant. For this reason, we will not rely completely on statistical tests, instead relying sometimes on outside knowledge like the observation that a five-second difference is not practically significant even if it is statistically significant. The final report will include a detailed discussion of model validation including some tables comparing simulation and actual data.

One of the advantages of the verified and validated MACSIM model is its capability to simulate scenarios at selected weigh stations that would be otherwise impossible to perform. For example, it is forecasted that by the year 2004 the number of trucks on the U.S. highways will increase by 13.4 percent.” By the same date the number of transponder-equipped trucks may also increase. The MACSIM model, run under the new traffic condition, will be able to aid states in their decision-making process concerning whether to design new weigh stations or redesign existing facilities.

Resources Needed for Conducting the Test

Hardware

Hardware required for the data collection team is described in the Weigh Station Throughput Test Plan. The simulation modeling phase of this test will require a personal computer equipped with a Pentium based processor and sufficient RAM and disc space to efficiently run the Arena software. In addition, a 17-inch monitor will be required to view and develop the graphics portion of the Arena simulation models.

Software

The primary software needs for this test consist of the Arena simulation package, a database/spreadsheet package, and statistical analysis software. One software license for the Arena Research Edition will be purchased for this test. This package offers unlimited model building and animation creation. It is identical to the Arena commercial package except that it cannot be used for commercial or consulting purposes.

The database/spreadsheet and statistical analysis software needs are detailed in the Weigh Station Throughput Test Plan.

Consumable Items

None

Staff and Responsibilities

Data collection staffing and responsibilities are detailed in the Weigh Station Throughput Test Plan. Dr. Ali Kamyab and one research assistant will develop the simulation models. Dr. Hal

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11 ***US. Freight Transportation Forecast** . . . **to** 2004.* Prepared by DRI/McGraw-Hill. Submitted to the American Trucking Associations Foundation. Second Annual Report. February, 1996. p. 1.5.

Stern will provide statistical guidance and support. Mr. Jim York will supervise any additional data collection efforts that may be required to calibrate the models.

Test Duration

See Test Schedule.

Statistics and Sample Size

Details concerning data collection are discussed in the Weigh Station Throughput Individual Evaluation Plan. Statistics and sample size considerations affecting the simulation study are of a different nature than those considered elsewhere. Once a simulation model is developed it can be used to provide precise estimates of system behavior (assuming simulation assumptions are correct). Precision of estimates is not limited by sample size considerations because the simulation model can be run for indefinite time periods.

The number of simulation models developed for this test is based on the needs of the project partners (states and provinces participating in the MACS operational test) and the guidance of the Evaluation Task Force. The primary goal of our site selection was to meet the Evaluation Task Force requirements of developing models for stations from each of the three weigh station design types (static scale, ramp WIM, and high-speed ramp MM), unique weigh stations, and at least one station from each state or province. Based on these needs and instructions from the Evaluation Task Force, seven sites, shown in Table Six, have been tentatively selected for simulation modeling. It is anticipated that a simulation model for one design type will be easily modified to model other stations of the same type. The secondary goal of the evaluation team was to include the least efficient and most efficient sites (based on weigh station throughput) for each of the design types. The preliminary site selection decisions are based partly on phone interviews with enforcement officials because data are available for only a limited number of sites. Final site selection will be revised should the results of the Weigh Station Throughput Tests reveal significantly different traffic or weigh station operating conditions than currently anticipated.

Another consideration in selecting the sites was to choose those stations that are examined in other test plans, such as the Fuel Consumption Test Plan. The MACS project partners will benefit by selecting sites examined in these other tests because the final evaluation report will include a comprehensive analysis of the expected effects of electronic clearance at these sites.

Table Six: Preliminary Simulation Modeling Sites

Station Name	Design Type	Peak Hours	Peak Queue Conditions
Halton, ON (Eastbound)	Ramp WIM	7:00-9:00 am	Frequent full-queues resulting in manual closing as frequently as 6 times/hour during peak periods.
Monroe, MI (Northbound)	Ramp WIM	6:00-9:00 am	Frequent 2,000 ft queues during peak hours. No station closings.
Hancock, OH (Southbound)	Static Scale	6:00-9:00 am & 3:00-6:00 pm	Queue overflows onto mainline 7-9 times per hour during peaks.
Kenton, KY (Southbound)	Ramp WIM	9:00-11:00 am	Seldom full queues. No station closings.
Knox, TN (Northbound)	Static Scale	6:00am-5:00 pm	Consistently full-queue, vehicles instructed to bypass when full.
Lowndes, GA (Southbound)	Ramp WIM	7:00-l 1:00 pm	Seldom full queues. Manual station closing when full.
Charlotte, FL (Southbound)	High-Speed Ramp WIM	10:00 am-5:00 pm	No full queues. No station closings.

System Conditions

This test will only affect the system during the data collection phase.

Traffic Conditions

The MACSIM model will have the capability to simulate a number of traffic conditions by varying the vehicle arrival rates. Based on the results of the Weigh Station Throughput Timing Tests, the models will illustrate current peak and non-peak conditions. The models will also be able to illustrate forecasted traffic conditions based on credible truck demand forecasts. For example, one recent study commissioned by the ATA Foundation, Inc. revealed a significant increase in the number of commercial vehicles and miles traveled per vehicle between 1994 and the year 2004.[12] The results of that study are shown in Table Seven.

The vehicle arrival rate is among the variables which can easily be changed in the MACSIM model. The trucks' arrival rate for a particular weigh station for the year 2004 can be estimated from our current data and the forecasted increase. Changes in the estimated arrival rate and other forecasted changes, such as in the truck population equipped with transponders, can be incorporated into the model. Running the model under plausible future traffic condition will provide estimates of future processing time and other quantities of interest for the simulated weigh station.

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12 ***U.S. Freight Transportation Forecast . . . to*** 2004. Prepared by DRI/McGraw-Hill. Submitted to the American Trucking Associations Foundation. Second Annual Report. February, 1996. p. 15.

Table Seven: Commercial Vehicle Population Forecast for the Period 1996--2004

Forecast Element	1,994	2,004	Cumulative Growth
Truck population (thousands)			
Class 8	1,535	1,723	12.2%
Classes 6/7	1,335	1,513	13.3%
Classes 3-5	1,280	1,471	14.9%
Total	4,151	4,706	13.4%
Miles per truck per year (thousands)			
Class 8	64.20	73.20	14.1%
Classes 6/7	22.90	27.00	17.9%
Classes 3-5	18.30	20.50	12.0%
Ton-Miles (billions)			
Class 8	1.10	1,410	28.0%
Classes 6/7	96.00	129.00	33.6%
Classes 3-5	29.00	38.00	28.7%
Total	1,227	1,576	28.5%

Environmental Conditions

None

Safety Considerations

The primary safety considerations for this test plan concern the data collection effort. These are detailed in the Weigh Station Throughput Test Plan.

Input Data

Data will be collected concerning vehicle arrival rates, travel speeds, static scale service times (i.e., primary service time), and inspection times (also referred to as secondary service times) as part of the Weigh Station Throughput Test Plan. Details concerning the collection of these data are provided on pages 14-20 of this document. Summaries of these data (e.g., typical arrival rates) will be used to run the simulation model and validate the output of the simulation model. Results of simulations are also computer-generated data files, which will be used for subsequent analyses. These files include estimates of the effect of electronic clearance on variables of interest such as queue length, number of unauthorized bypasses, and travel time savings.

POST-TEST ACTIVITIES

Participants in the Post-Test Activities

Participants in the post-test activities include Mr. Jim York and Dr. Ali Kamyab at CTRE, members of the data collection team at the Kentucky State University, and Dr. Hal Stem at the Iowa State University Department of Statistics.

Debriefings

The data collection team leader will prepare a written debriefing for each test site that provides a summary of the test events, test conditions, and special circumstances that occurred during the data collection sessions. The test events summary should consist of a brief paragraph describing the method used by enforcement officials to process vehicles through the weigh station and a description of the data collection point locations (e.g., how the point was marked and the distances to nearest reference points). The test conditions summary should consist of a description of the traffic conditions and environmental conditions encountered during the data collection sessions. The special circumstances summary should describe any special enforcement or inspection efforts or construction activities in the vicinity of the weigh station that occurred during the sessions. The purpose of this debriefing is to provide information for data analysis personnel that would highlight or explain any abnormal test data. Such abnormal data would be excluded from the data set if a subsequent analysis indicates that such observations are erroneous or have a dramatic effect on the simulation model input data. This debriefing should be completed within three days of completion of the data collection sessions.

Simulation debriefing would include documentation of the capabilities and limitations of the simulation software.

Equipment Tear Down

None

Data Retention Plan

Data collected will be provided for simulation modeling in summary form. These summaries will be prepared by CTRE staff. Examples include the number of trucks arriving during each hour of observation, typical velocity of arriving trucks, static scale service times, and proportion of trucks required to undergo inspections. Tables of such results will be provided as part of the final report. The final report will also include numerous tables containing simulation results.

DATA REDUCTION AND ANALYSIS

Participants

Participants in this phase of the test include Dr. Ali Kamyab, Mr. Jim York, and one graduate level research assistant at CTRE and Dr. Hal Stern.

Hypotheses or Expected Results

It is anticipated that simulations will show a relationship between the proportion of trucks equipped for electronic clearance (a quantity that can be varied in simulation) and unauthorized bypasses and queue length. Greater levels of transponder-equipped trucks are expected to lower average queue length and therefore lower the number of unauthorized commercial vehicle bypasses.

Input Data

The simulation requires as input descriptions of the distribution and frequency of commercial vehicle arrivals, the distribution of speeds of commercial vehicle arrivals, and the frequency and duration of servicing of vehicles at the weigh station (including primary and secondary inspection times). These quantities are discussed below. Required numerical values (e.g., mean arrival rate) will be determined from data collected as described in other evaluation plans.

- **Interarrival Rates:** Under the assumption that arrival of vehicles is randomly distributed over time, the Poisson distribution can be used to predict the number of vehicle arrivals in a given time and, in turn, the exponential distribution can be used to describe mean vehicle inter-arrival times (i.e., time between vehicle arrivals). The interarrival times collected during Pilot Study Two support the above hypothesis. Given the mean value for the vehicle arrival rate, Arena will automatically generate entities (in this case trucks) according to the exponential distribution.
- **Approach Speed:** The approach speed will be input for the simulation model as either a constant (equal to the average observed value) or in the form of a statistical distribution. Depending on the nature of the collected data, the normal distribution may be used to describe the variation in approach speeds of commercial vehicles.
- **Static Scale Service Time:** The time that trucks spend on the static scale will be input as either a constant equal to the average observed value or in the form of a statistical distribution. According to data collected during the Pilot Study Two and a study done at a Canadian weigh station, the Erlang distribution may be used to describe the distribution of static scale service times for the model.[13]
- **Inspection Service Time:** The inspection service time is the time interval required for a routine safety inspection. The inspection service time will be input as either a constant

[13] Edward S. K. Fekpe, Alan M. Clayton and Attahim Sule Alfa. ***Aspects of Perjbrmance of Truck Weigh Stations.*** Canadian Journal of Civil Engineering, Vol. 20, 1993. pp. 380-385.

(e.g., the average observed value) or described by a random variable with the Erlang distribution.

- **Inspected Truck Frequency:** The proportion of trucks arriving at the weight station that are directed to the inspection area will be input as a parameter (values used will be based on observed data). During simulation the inspection decision for each truck will be generated based on the input parameter.
- **Truck Specifications:** The distribution of truck specifications, such as its weight and size class, will be input in a form of discrete distribution (e.g., 30 percent at 80,000 pounds, 50 percent at 60,000 pounds, and 30 percent at 40,000 pounds for weight and 24 percent class five, 35 percent class seven, and 41 percent class eight for size) or using other statistical distributions. The relevant distribution will be based on data collected or other information provided in the literature.

Methods, Algorithms, and Equations

The principal tool in this part of the evaluation is a simulation model. A microscopic (i.e., truck level) simulation model (i.e., MACSIM) will be developed to determine the number of unauthorized bypasses, queue lengths, and processing times at the selected weigh stations along the I-75 corridor. A weigh station will be modeled as a multiple-server facility, because at any given time it provides services to a number of trucks at its different components (i.e., static scale and inspection areas). Furthermore, the MACSIM model will assume no interaction between vehicles on the freeway; that is, no car-following and lane-changing algorithms will be included in the model. Therefore, the freeway, modeled in the link module, will be considered as only a feeder. Vehicle arrivals on the freeway will be described by the exponential distribution.

The node module of the MACSIM model, on the other hand, will simulate the arrival and departure of trucks in the weigh station. Vehicle service times at the weigh stations will be described by appropriate discrete and continuous distributions. The MACSIM model is a stochastic model, since the mean interarrival time of vehicles will be described by a probability distribution.

Statistical Tests

The role of statistical tests in this evaluation test varies depending on the phase of the simulation study. As described earlier (Description of Evaluation Test Activities), statistical tests can be used to compare simulation results to results obtained via data collection as part of the process of validating the simulation model. Results obtained during data collection are based on a sample which is used to represent the entire population of interest (all commercial vehicles or all hours of operation). Statistical methods are useful in the validation setting because the sampling that is used during data collection introduces variability (i.e., we realize that a different sample would give different results). Once the simulation model has been validated, the role of statistical tests diminishes. The reason for this is that in the simulation context the population of interest (i.e., the simulation model) is available for study. Results can be obtained to whatever accuracy is required by increasing the amount of time for which the simulation is carried out.

A complete analysis of simulation results may also introduce the need for statistical tests. It may be interesting to describe the effect of increasing the proportion of MACS-equipped vehicles on queue length and unauthorized bypasses. To study this effect, a number of scenarios can be explored via simulation. It may not, however, be possible to simulate all scenarios of interest due to time constraints. In that case, statistical methods can be used to try to infer the consequences of several untried scenarios. Of course, ultimately it is possible to rerun the simulation as often as possible.

Output Data

The simulation model will produce output data including the number of unauthorized bypasses, queue lengths, and processing time at a weigh station. The processing time may consist of the amount of time that trucks spend at each component of a weigh station (e.g., in the queue, in the static scale, etc.). The Arena software is capable of providing detailed information about any feature of the simulated system. Therefore, there will be no limitations on the scope of output data.

Accuracy Requirements

Sample data will be used to validate the simulation model. We expect that the model will reproduce traffic patterns to a suitable degree of accuracy. This will be assessed using statistical methods described earlier (see discussion statistical validation methods in paragraph five of page 41).

Hardware, Software

Simulation software will provide the bulk of the analysis. Suitable computer(s) to run the software are required.

REPORTING REQUIREMENTS

A final report outline will be developed during the course of the research. As part of the analysis and reporting phase, draft final report outlines will be developed and submitted to Evaluation Task Force members for review and comment. The final report outline will reflect the comments and input from committee members, and the final report will be developed according to the final outline.

BUDGET

The budget for conducting the Simulation Modeling Test is provided in Table Eight. This budget provides two separate expense subtotals (e.g., personnel and equipment and travel). The total project budget for this plan is the sum of the personnel and equipment subtotals and the Iowa State University indirect cost. The project term begins on June 1, 1996 and runs through March 3 1, 1998 The budget has been reviewed and approved, as shown in Exhibit A in the Letter of Transmital, by the Director of the Center for Transportation Research and the Contracts and Grants Officer for the Iowa State University.

Table Eight: Simulation Modeling Test Plan Budget

Personnel Budget	Time (Hrs.)	Rate/ Hour	Budget
Faculty			
Tom Maze	30	***$55.94***	$1,678
Hal Stem	260	$35.47	$9,222
Professional and Scientific			
Jim York	***693***	$19.87	$13,774
Bill McCall	60	$38.20	$2,292
Marcia Brink	12	$16.51	$198
Jan Graham	87	$18.69	$1,618
Merit Staff			
Dianne Love	112	$14.44	$1,618
Secretary	118	$13.74	$1,618
Research Students			
1 Iowa State University Student (Data Entry)	520	$14.64	$7,611
Post Doctorial Research Associate			
Dr. Ali Kamyab	2,080	***$20.19***	$42,000
Fringe Benefits			
Faculty Fringe @24.55%		24.55%	$2,676
Professional and Scientific Fringe @3 0.8%		30.80%	$5,508
Merit Fringe @ 39.45%		39.45%	$1,277
Research Student Fringe @$625/year		$178.00	$534
Post Doctoral Fringe @ 16.14%		16.14%	$6,779
Total Personnel Budget			$98,402
Equipment and Travel Budget			
Supplies			$250
Equipment (Computer and Monitor)			$3,500
Phone, postage, and communications equipment rent			$2,000
Subcontracts			
Kentucky State University (6 Research Assitants)	292	$14.53	$4,239
Kentucky State University Van	1,232	$0.22	$271
Meals and Lodging Expense			$2,185
Additional Domestic Travel — Cost Per Trip		$1,160.00	$6,240
Total Equipment and Travel Budget			***$18,685***
Subtotal Project Budget			$117,087
Indirect Cost @25%			$29,272
Total Project Budget			**$146,359**

APPENDIX

Appendix One: Throughput Timing Data Collection Schedules

Data Collection Schedule: Group 1

Day Number	Station Name	Time Period	Total Staff Hours/Day
1 Tuesday	Halton, Ontario (EB) o	7:00-8:06 A	
	Halton, Ontario (WB) n	9:00-10:06 A	
	Halton, Ontario (EB)	11:00-12:06 P	
	Halton, Ontario (EB)	2:00-3:06 P	
	Halton, Ontario (WB) n	4:00-5:06 P	
	Halton, Ontario (WB)	5:30-6:36 P	10:36
2 Wednesday	Halton, Ontario (EB) o	8:00-9:06 A	
	Halton, Ontario (WB) n	10:00-11:06 A	
	Halton, Ontario (EB)	12:00-1:06 P	
	Halton, Ontario (WB) n	3:00-4:06 P	10:06
	Halton, Ontario (WB)	4:30-5:36 P	
	Halton, Ontario (EB)	6:00-7:06 P	
	Travel to Middlesex, Ontario (79.5 miles)		
3 Thursday	Middlesex, Ontario (WB) n	7:00-8:06 A	
	Middlesex, Ontario (EB) o	9:00-10:06 A	
	Middlesex, Ontario (EB) o	11:00-12:06 P	
	Middlesex, Ontario (WB) n	2:00-3:06 P	
	Middlesex, Ontario (WB)	3:30-4:36 P	
	Middlesex, Ontario (EB)	5:00-6:06 P	10:06
4 Friday	Middlesex, Ontario (WB) n	8:00-9:06 A	
	Middlesex, Ontario (EB) o	10:00-11:06 A	
	Middlesex, Ontario (WB) n	12:00-1:06 P	
	Middlesex, Ontario (EB)	3:00-4:06 P	
	Middlesex, Ontario (WB)	4:30-5:36 P	
	Middlesex, Ontario (EB)	6:00-7:06 P	10:06

o Indicates reported peak hour in the East or North directions
n Indicates reported peak hour in the West or South directions

Data Collection Schedule: Group 2

Day Number	Station Name	Time Period	Total Staff Hours/Day
1 Monday	Hancock, Ohio (SB) n	7:00-8:06 A	
	Hancock, Ohio (SB)	9:00-10:06 A	
	Hancock, Ohio (SB)	11:00-12:06 P	
	Travel to Wood, Ohio (17 miles)		
	Wood, Ohio (NB) o	2:00-3:06 P	
	Wood, Ohio (NB) o	3:30-4:36 P	
	Wood, Ohio (NB) o	5:00-6:06 P	10:06
2 Tuesday	Wood, Ohio (NB) o	8:00-9:06 A	
	Wood, Ohio (NB)	10:00-11:06 A	
	Wood, Ohio (NB)	12:00-1:06 P	
	Travel to Hancock, Ohio (17 miles)		
	Hancock, Ohio (SB) n	3:00-4:06 P	
	Hancock, Ohio (SB) n	4:30-5:36 P	
	Hancock, Ohio (SB)	6:00-7:06 P	
	Travel to Monroe, Michigan (58 miles)		11:06
3 Wednesday	Monroe, Michigan (NB) o	7:00-8:06 A	
	Monroe, Michigan (NB)	9:00-10:06 A	
	Monroe, Michigan (NB)	11:00-12:06 P	
	Monroe, Michigan (SB)	2:00-3:06 P	
	Monroe, Michigan (SB) n	3:30-4:36 P	
	Monroe, Michigan (SB) n	5:00-6:06 P	
	Travel to Essex, Ontario (48 miles)		11:06
4 Thursday	Essex, Ontario (WB) n	7:00-8:06 A	
	Essex, Ontario (WB) n	9:00-10:06 A	
	Essex, Ontario (EB) o	11:00-12:06 P	
	Essex, Ontario (EB) o	2:00-3:06 P	
	Essex, Ontario (EB)	3:30-4:36 P	
	Essex, Ontario (EB)	5:00-6:06 P	10:06
5 Friday	Essex, Ontario (WB) n	8:00-9:06 A	
	Essex, Ontario (EB) o	10:00-11:06 A	
	Essex, Ontario (EB) o	12:00-1:06 P	
	Essex, Ontario (WB)	3:00-4:06 P	
	Essex, Ontario (WB)	4:30-5:36 P	
	Essex, Ontario (WB)	6:00-7:06 P	10:06

Data Collection Schedule: Group 4

Day Number	Station Name		Time Period	Total Staff Hours/Day
1 Tuesday	Kenton, Kentucky (SB)	n	7:00-8:06 A	
	Kenton, Kentucky (SB)		9:00-10:06 A	
	Kenton, Kentucky (SB)		11:00-12:06 P	
	Travel to Scott, Kentucky (38 miles)			
	Scott, Kentucky (NB)		2:00-3:06 P	
	Scott, Kentucky (NB)	o	4:00-5:06 P	
	Scott, Kentucky (NB)	o	5:30-6:36 P	10:06
2 Wednesday	Kenton, Kentucky (SB)	n	8:00-9:06 A	
	Kenton, Kentucky (SB)		10:00-11:06 A	
	Kenton, Kentucky (SB)		12:00-1:06 P	
	Travel to Kenton, Kentucky (38 miles)			
	Scott, Kentucky (NB)	o	3:00-4:06 P	
	Scott, Kentucky (NB)	o	5:00-6:06 P	9:36
3 Thursday	Scott, Kentucky (NB)	o	7:00-8:06 P	
	Travel to Knox, Tennessee (241 miles)			
	Knox, Tennessee (SB)	n	4:00-5:06 P	
	Knox, Tennessee (SB)		5:30-6:36 P	10:36
4 Friday	Knox, Tennessee (SB)	n	7:00-8:06 A	
	Knox, Tennessee (NB)	o	9:00-10:06 A	
	Knox, Tennessee (SB)	n	11:00-12:06 P	
	Knox, Tennessee (NB)	o	2:00-3:06 P	7:06

Data Collection Schedule: Group 4

Day Number	Station Name	Time Period	Total Staff Hours/Day
1 Monday	Monroe, Georgia (NB)	7:00-8:06 A	
	Monroe, Georgia (NB)	9:00-10:06 A	
	Monroe, Georgia (NB) o	11:00-12:06 P	
	Monroe, Georgia (SB) n	2:00-3:06 P	
	Monroe, Georgia (SB)	3:30-4:36 P	
	Monroe, Georgia (SB)	5:00-6:06 P	10:06
2 Tuesday	Monroe, Georgia (SB)	8:00-9:06 A	
	Monroe, Georgia (SB)	10:00-11:06 A	
	Monroe, Georgia (SB) n	12:00-1:06 P	
	Monroe, Georgia (NB) n	3:00-4:06 P	
	Monroe, Georgia (NB)	4:30-5:36 P	
	Monroe, Georgia (NB)	6:00-7:06 P	10:06
3 Wednesday	***Travel to Lowdes, Georgia (163 miles)***		
	Lowdes, Georgia (NB)	4:00-5:06 P	
	Lowdes, Georgia (SB)	6:00-7:06 P	
	Lowdes, Georgia (SB) n	7:30-8:36 P	8:06
4 Thursday	Lowdes, Georgia (NB) o	9:00-10:06 A	
	Lowdes, Georgia (NB) o	11:00-12:06 P	
	Lowdes, Georgia (SB)	2:00-3:06 P	
	Lowdes, Georgia (NB)	4:00-5:06 P	
	Lowdes, Georgia (SB)	6:00-7:06 P	
	Lowdes, Georgia (SB) n	8:00-9:06 P	11:06
5 Friday	Lowdes, Georgia (NB) o	10:00-11:06 A	
	Lowdes, Georgia (NB) o	12:00-1:06 P	
	Lowdes, Georgia (SB)	2:00-3:06 P	4:06

Data Collection Schedule: Group 4

Day Number	Station Name	Time Period	Total Staff Hours/Day
1 Tuesday	Charlotte, Florida (NB)	7:00-8:06 A	
	Charlotte, Florida (NB)	9:00-10:06 A	
	Charlotte, Florida (NB) o	11:00-12:06 P	
	Charlotte, Florida (NB) n	2:00-3:06 P	
	Charlotte, Florida (NB) n	3:30-4:36 P	
	Charlotte, Florida (NB)	5:00-6:06 P	10:06
2 Wednesday	Charlotte, Florida (NB)	8:00-9:06 A	
	Charlotte, Florida (NB) o	10:00-11:06 A	
	Charlotte, Florida (NB) o	12:00-1:06 P	
	Charlotte, Florida (NB) n	3:00-4:06 P	
	Charlotte, Florida (NB)	4:30-5:36 P	
	Charlotte, Florida (NB)	6:00-7:06 P	10:06

Appendix Two: Monthly Overview of Combined Data Collection Schedule

June

1996 1996

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1
2	3	4	5	6	7	8 Fuel Team leaves for Monroe, Georgia
9 Day 1	10 Day 2	11 Day 3	12 Day 4	13 Day 5	14 Day 6	15 Day 7
Fuel Consumption Testing in Monroe, Georgia						
16 Fuel Team remains in Monroe Time Team leaves for Monroe	17 Day 1	18 Day 2	19 Day 3	20 Day 4	21 Day 5	22 Both Teams return home
	Weigh Station Throughput Timing: Monroe, Georgia → Lowndes, Georgia (Group 4)					
23	24	25	26	27	28	29
30						

July

1996 1996

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1	2	3	4 Fourth of July (Holiday)	5	6
7	8	9	10	11 Fuel Team leaves for Charlotte, Florida	Day 1 12 (Charlotte)	Day 2 13
Day 3 14 Fuel Consumption Testing in Charlotte, Florida	Day 4 15	Day 5 16	Day 6 17	Day 7 18	Day 8 19	Day 9 20
21 Fuel Team remains in Charlotte	22 Fuel Team remains in Charlotte Time Team leaves for Charlotte	Day 1 23 Weigh Station Throughput Timing: Charlotte, Florida (Group 5)	Day 2 24	25 Both teams return home	Day 5 26	27
28	29	Day 1 30 Weigh Station Throughput Timing: Kenton, Kentucky→ Knoxville, Tennessee (Group 3)	Day 2 31	Day 3 Aug 1	Day 4 2	

August

1996 1996

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
				Day 3 1	Day 4 2	
				(last 2 days in Knoxville)		
4	Day 1 5	Day 2 6	Day 3 7	Day 4 8	Day 5 9	1
	Fuel Consumption Testing in Knoxville, Tennessee					
11	Day 1 12	Day 2 13	Day 3 14	Day 4 15	Day 5 16	1
	Weigh Station Throughput Timing: Halton, Ontario → Middlesex, Ontario (Group 1)					Fuel Team travels to Monroe, Michigan
Day 1 18	Day 2 19	Day 3 20	Day 4 21	Day 5 22	Day 6 23	Day 7 2
Fuel Consumption Testing in Monroe, Michigan						
25 Classes Begin	26	27	28	29	30	3

1996 **September** 1996

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15 Fuel Team leaves for Findlay, Ohio	16 Fuel Consumption Testing in Findlay, Ohio	17	18	19	20	21 Fuel Team remains in Findlay Time Team leaves for Findlay
22	23 Day One Weigh Station Throughput Timing: Findlay, Ohio→Essex, Ontario (Group 2)	24 Day Two	25 Day Three	26 Day Four	27 Day Five	28 Both Teams Leave
29	30					